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STUDIES ON THE NESTING CYCLE OF THE CALIFORNIA VALLEY QUAIL IN 1937¹

By BEN GLADING

San Joaquin Experimental Range

Introduction

The foothills of the western slope of the Sierra Nevada of California have long been a favorite hunting ground for sportsmen, particularly those residing in the San Joaquin and Sacramento valleys. This area abounds in California valley quail (*Lophortyx californica vallicola*), western mourning doves and cotton-tail rabbits.

There are many ecological problems concerning the lives of these game species which are in need of study in order to answer certain game management questions. Sumner (1935) has provided details on the California quail in the Santa Cruz Mountains of the humid coast region, but knowledge of valley quail for other, quite different environments such as the foothill region of the Upper Sonoran Zone is, for the most part, lacking. A complete study is needed for each major ecological division of the California quail's range. In order to provide for this in the Sierra foothills, the Cooperative Quail Management Study Committee was organized.²

The area chosen for the study is the San Joaquin Experimental Range, situated in the foothills of Madera County, 25 miles east of Madera, California. The Range includes 4500 acres of rolling hills and swales with occasional small canyons; the altitude is 700 to 1500 feet. The soil is for the most part granite sand with small areas of adobe in the swales. Granite and quartz outcrops form a prominent feature of the landscape.

The San Joaquin Experimental Range has been selected by the United States Forest Service as an example of typical foothill grazing country in the interior of California. Experiments are in progress here on range and livestock management in cooperation with the University of California and other agencies. It is therefore well adapted for a study of game management in this foothill region.

There is more man-caused interference to wildlife on this Range than is the case on most foothill ranches. Crews engaged in construc-

¹ Submitted for publication, July, 1938. Published by permission of the U. S. Forest Service.

² The Committee is composed of Tracy I. Storer, chairman, and J. T. Emlen, Jr., of the University of California College of Agriculture; E. E. Horn of the U. S. Biological Survey; E. I. Kotok, M. W. Talbot, H. H. Biswell, and J. W. Nelson of the California Forest and Range Experiment Station, U. S. Forest Service; and F. P. Cronemiller and F. W. Johnson of Region 5, U. S. Forest Service. Messrs. Storer and Horn form a special technical advisory committee. Funds for the project are supplied by Region 5, U. S. Forest Service. The writer has been engaged by the Committee as a resident investigator at the San Joaquin Experimental Range. Additional help in various projects was obtained through the use of U. S. Forest Service Junior Assistants to Technicians and Civilian Conservation Corps enrollees for manual labor. Studies began in December, 1936, and are still in progress (July, 1938).

tion of fences, roads, etc., and technical men in various lines of research create more disturbance here than on private lands. Cattle are of course present in most of the pastures on the Experimental Range.

The common trees of the area are blue oak (*Quercus douglasii*), interior live oak (*Q. wislizenii*), digger pine (*Pinus sabiniana*), and California buckeye (*Aesculus californica*). These are scattered, giving the landscape a rather open appearance. Of shrubs, buckbrush (*Ceanothus cuneatus*), "white thorn" (*C. divaricatus*), manzanita (*Arctostaphylos mariposa*), and bush lupine (*Lupinus albifrons*) are the most common. On some parts of the Range the shrubs occur in small dense patches, otherwise they are scattered. The small vegetation is composed chiefly of annual weeds and grasses, largely introduced species; broadleaf filaree (*Erodium botrys*), soft-chess brome grass (*Bromus mollis*), and fescue grass (*Festuca megalura*) are the most abundant. This annual type vegetation, characteristic of the foothill belt, supplies an abundance of seed.

Weather conditions at the Range are representative of the foothill belt. The average annual rainfall is about 17 inches, received mostly in the months from October to April; little or no rain falls from May to September. During the dry summer season the daily maximum temperature commonly goes over 100° F., and has reached 115° F. Winter minima are slightly below freezing; snow falls only rarely. During the summer the relative humidity is low (average daily minima from 15 to 20 per cent). No fog or dew is present in the summer.

Excellent studies on the nesting habits of several American quail are available, such as that on the eastern bobwhite by Stoddard (1931), on the Gambel quail by Gorsuch (1934), and on the California quail by Grinnell, Bryant and Storer (1918), but up to the present, this important phase of valley quail life has remained untouched from the game management point of view. Sumner (1935) felt it inadvisable to conduct such a study for fear of setting up unnatural conditions, and leading curious predators to the nests.

The Committee felt that major emphasis should be placed on the nesting cycle. Preliminary study suggested that loss of adult birds due to predation was not a major factor at the current population level. Roosting and escape cover seemed adequate over a large part of the Range for a much larger number of quail than were present. The local population of quail approaches, and in some small areas exceeds the hypothetical maximum concentration of one bird per acre put forward by Errington and Hamerstrom (1936) and others for the eastern bobwhite. Yet local reports of much heavier valley quail concentrations in the past imply that the maximum carrying capacity of this foothill country may be several fold greater. Some observations by Horn (1938, pp. 58-60) suggest that regulation of predators during the nesting season might build up the quail population. In view of these and other considerations a complete, quantitative study of nesting was deemed desirable.

General Habits of the Quail Prior to Nesting

Studies of the behavior of flocks and of individuals carried on throughout 1937 showed that until early in March the coveys comprised about 30 birds each. Then groups of from 2 to 10 were to be

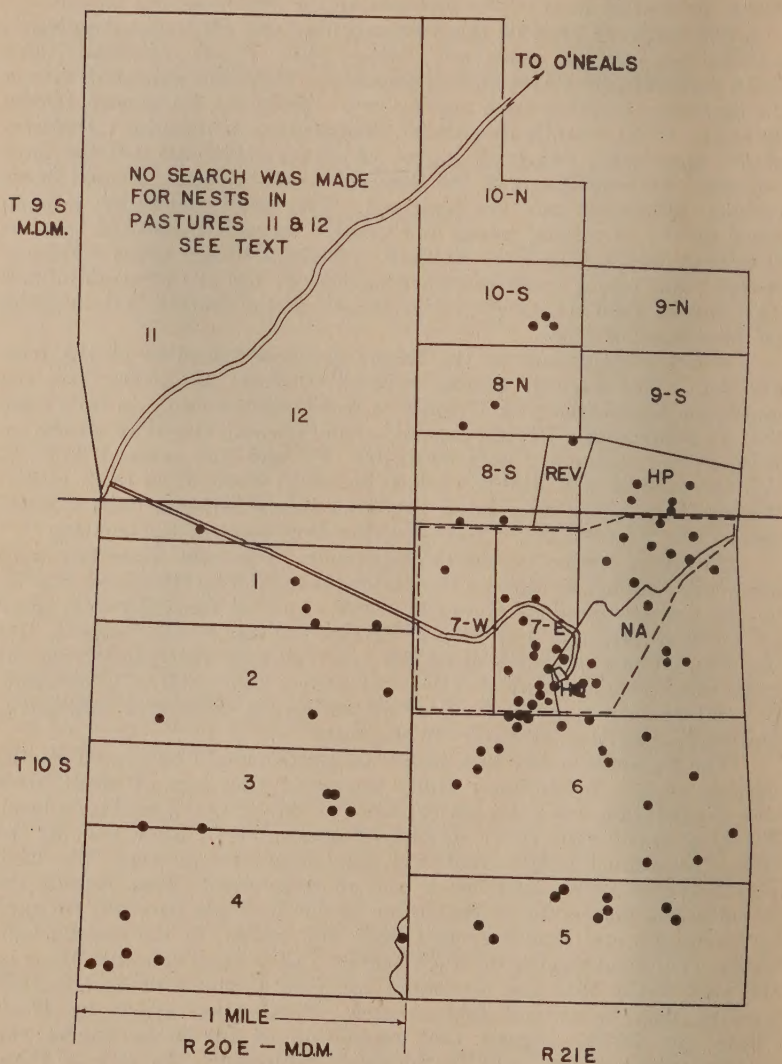


FIG. 101. Map of the San Joaquin Experimental Range, near O'Neals, Madera County, California, showing various pastures and other divisions, together with location of 93 nests of valley quail studied in 1937. Numbers refer to various pastures. HQ: headquarters building, NA: natural area, HP: horse pasture, Rev: revegetation area. The dotted lines bound the area on which ground squirrels were poisoned in 1936 and 1937.

seen during the loafing hours. These smaller groups usually recombined for the evening feeding period and for roosting. At this season the birds became very secretive, and it was increasingly difficult to make observations on the natural behavior of courtship and mating. The picture has been fitted together with occasional observations. By the last of April, coveys were largely broken into pairs; it was then a common thing to see a group of quail assembled for the evening feeding, cross a road, one pair at a time, the whole party taking as long as 10 minutes to cross. The first pair might be some 50 yards distant when the last cock and hen passed.

During April and May, frequent "cows!" (Sumner's call of an unmated cock) were heard. The low assembly call from a hen would bring several crowing cocks to her side. On one occasion, after one of these meetings, a pair was seen to go into a dense patch of *Ceanothus* and a loud series of "whip-whips" and clucking notes could be heard accompanied by scuffling in the leaves. This was interpreted as being an act of copulation.

Methods of Locating Nests

During this period of pairing, two men were constantly in the field, observing paired birds and looking for possible nests. The first definite attempt at nesting was noted on April 22. In the prenesting period, about 50 markers were placed at spots from which paired birds were flushed, in order to determine if these trysting places would be chosen as nesting sites. No nest was subsequently found in the immediate vicinity of any such marker.

In May, a crew of from four to six men was in the field daily, searching for nests. The method employed was to examine (theoretically at least) every foot of the ground in certain areas. Pastures 1, 3, 4, 6, the Natural Area and the Horse Pasture (see Fig. 101) were covered at least once by this crew, and 17 of the 50 nests found during May were so discovered. The remaining 33 were spotted either by investigators on observational hikes or by field workers engaged in other lines of endeavor.

Most of the nests were happened upon accidentally. Some were found by watching the actions of mated birds. A quail cock resting in an oak tree during the middle of the day was considered to be in the vicinity of a sitting hen, and several nests were found by searching the area about such a male. Search by individual observers was more profitable than mass effort. All nests located after June 1 were discovered by individuals, mostly by the writer and his assistant.

Long ropes were dragged between two men in the hopes of flushing incubating birds from their nests. This method was given a fair trial but proved almost useless due to the rocky and brushy nature of the country.

Period of Nesting

Ninety-six nests, including two just outside the Range fence, were found from April 22 to July 26, 1937, both dates inclusive.

The first (No. 1) was constructed by a cock thought to be the mate of a hen used as bait in a "cock and hen" trap. He abandoned

this attempt after being watched for two days, when his mate escaped from the trap.

Nest No. 2 was found on April 23, while under construction; it was subsequently successful. The earliest nests can safely be said to have been started during the last half of April. This checks well with what could be predicted by figuring back from the appearance of the first broods. In 1937 the first brood seen in the field was noted on May 26.

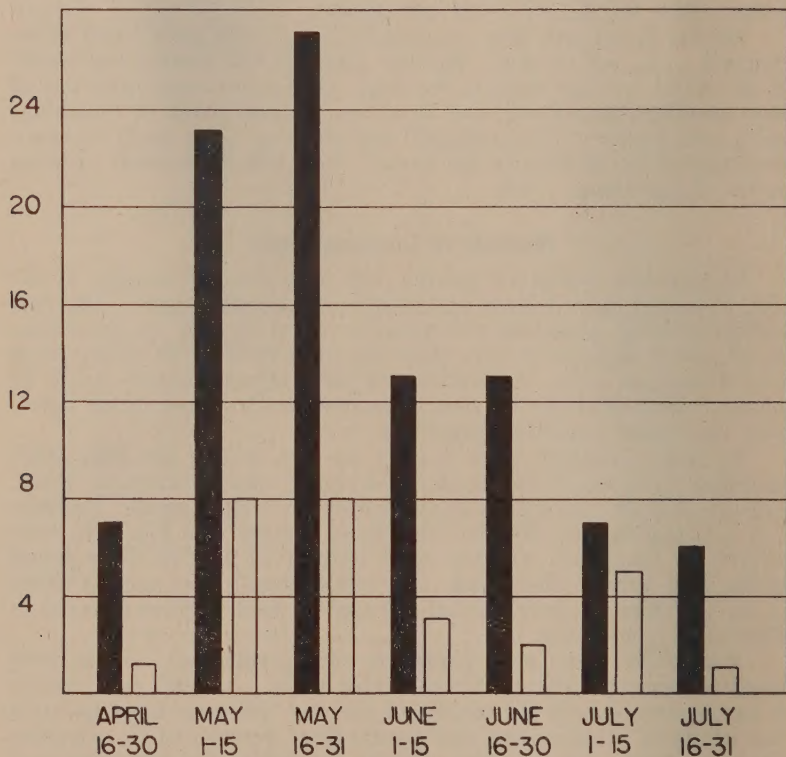


FIG. 102. Valley quail nests found (solid bars) on San Joaquin Experimental Range in 1937, by semi-monthly periods, together with numbers considered to have been robbed by ground squirrels (open bars).

Nesting reached a peak during May, according to the number of nests found during the several months: April, 7; May, 50; June, 26; July, 13.

In figure 102, the nests are grouped by semimonthly periods according to the dates when first seen. This grouping includes everything from those in early stages of construction to those from which broods had already hatched; the figure is an index of the nesting season as this term is commonly used.

There is a little evidence that some of the nests started during the latter part of the season were second attempts by birds that had had a previous nest either disturbed or destroyed. Nest No. 81 was accidentally destroyed by workmen who covered it with dirt on June 29. A pair of quail was observed about this spot several times during the next few days, and it was thought that they were making another attempt. A nest, No. 83, found on July 6, was about 15 yards from the site of No. 81, and then contained three eggs. Two other instances of parallel character were observed.

The last nest that came under observation, No. 93, was found on July 26, soon after having been destroyed by some unknown predator. Despite fairly active search during the ensuing fortnight and casual watch thereafter, no nests were found after this date.

Methods of Observation During Nesting Season

In view of Sumner's (1935) and other objections to detailed nesting studies of game birds, great care was exercised in this part of the study.

To get a rough check on the gross effect of nesting studies on the quail population, Pastures 11 and 12 (see Fig. 101) were left unstudied. This area had 629 quail (one bird per 1.74 acres) in February, 1937, compared with 1494 quail (one bird per 1.59 acres) on the remainder of the Range which was under observation for nests. In March, 1938, 500 quail (one per 2.19 acres) were counted on the unstudied area, and 1045 quail (one per 2.27 acres) were counted on the studied area. Other factors, such as moderate grazing over most of the studied area during the nesting season, as against light or no grazing on the control area may have affected the quail population on these areas to some degree; but the figures for 1938 do not demonstrate any disproportionate loss that could indisputably be said to have been caused by nesting studies.

Because of the possibility of upsetting natural conditions, great care was exercised in making observations. Most of the notes were made from daily visits on foot; the observer never approached closer than was necessary (30 inches or more) to see either the eggs or the sitting hen. If it was not possible to count the eggs without disturbing the cover, they were left until opportunity presented itself to make a proper check.

Nests located close to roads were ordinarily observed from an automobile. At several field nests a blind was used to obtain data on feeding and incubation periods of adults, time and other details about hatching, etc. The blind was always 30 feet or more from the nest.

No nest on the Range was touched by an investigator until permanently quitted by the attending quail; two on land adjacent to the Range were robbed for experiment.

Evidence that nesting studies present a fairly true picture of conditions as they existed naturally was obtained by comparing mortality figures of nests that were watched with those not watched (already destroyed or hatched when found). Table 1 summarizes information on these two groups of nests.

TABLE 1
Comparison of the Fates of Studied and Unstudied Nests

Fate	Nests observed while being attended by quail	Nests destroyed, abandoned or hatched when first seen	Total
Successful.....	14	3	17
Abandoned before laying.....	9	4	13
Abandoned after laying.....	3	2	5
Loss ascribed to ground squirrels.....	24	6	30
Loss ascribed to other predators.....	7	18	25
Destroyed by accident.....	4	2	6
Totals.....	61	35	96

With 61 observed nests versus 35 unobserved nests, there is a rough ratio of 2 to 1 for the two groups. The ratio of 14 to 3 for the successful nests would indicate that observation is not in itself prejudicial to success by the birds. It must be admitted, however, that nests from which young have already hatched are more difficult to find; hence the recorded ratio is probably inaccurate in this respect.

For abandoned nests, the ratio of 2 to 1 is fairly upheld although as noted below, field conditions have a very great influence on the figure.

Nests destroyed by predators show a 5 to 4 ratio. Depredations by ground squirrels (being difficult to find) are low with the "unobserved" nests, whereas work of the larger predators is high in the "unobserved" category, since their depredations are relatively easy to discover.

Details about all the 96 nests found in the summer of 1937 are given in table 2.

Nesting Materials and Construction

Dry grass (of the previous year in the case of early nests, of the current year in the case of later ones) comprised the lining of most nests. Dry willow leaves and various species of dried weeds were used in a few. In general nests were roofed, at least during the early part of incubation, by various types of vegetation, sometimes by overhanging rocks.

In the choice of nesting sites, it seems to be the custom for the female to take the lead, although the male undoubtedly assists, both in this activity and in the actual construction of the nest (*cf.* nest No. 1, discussed above). Hen No. 36702, evidently in search of a nesting site, was accidentally trapped on April 14. She was used for "bait" in a cock and hen trap and later escaped from this trap through a tunnel made by a ground squirrel in search of the grain inside of the hen's chamber. About a week later, she was found dead in the outer chamber of the same trap (unbaited) so it would seem that this particular hen had an unfortunate predilection for nesting at this site.

Paired birds disturbed while they are in the process of constructing a nest, even to the minor extent of being flushed because of an observer's presence 25 or 30 yards distant, in many cases will not return to that site. This happened with nests Nos. 4, 12, 13, 15, 37, 38 and 54. Whether the birds can not find their way back to the site or have a psychological aversion to the spot is a matter of conjecture.

TABLE 2

Valley Quail Nests on San Joaquin Experimental Range, 1937

Nest No.	Pas- ture No.	Date first seen	Located in cover type	Total eggs	Date of hatch	Number of young	Terminal date and cause of failure
1	7E	4/22	A				4/23—A.B.L. ¹
2	6	4/23	A	(7)	5/28	4	
3	7E	4/26	A				4/27—A.B.L. ²
4	5	4/28	A				4/28—A.B.L. ²
5	4	4/28	B	7			4/29?—Ground squirrel
6	8S	4/29	B	4			5/4?—Ground squirrel
7	6	4/30	B	?			? —Unknown
8	4	5/3	A	8			5/3?—A.A.L. ⁴
9	4	5/4	B	?			? —Ground squirrel
10	7E	5/4	B	?			? —Ground squirrel
11	5	5/5	F	14			5/9?—Ground squirrel
12	8S	5/6	D				5/6?—A.B.L. ²
13	6	5/7	D				5/7?—A.B.L. ²
14	H.P.	5/7	B	14?			? —Skunk
15	7E	5/10	B				5/10—A.B.L. ²
16	N.A.	5/11	A	1			? —A.A.L. ²
16a	N.A.	5/13	A	(17)			5/17—House cat
17	N.A.	5/11	A	(13)			6/5?—Unknown
18	N.A.	5/11	A				5/11—A.B.L. ²
19	H.P.	5/10	B	8			5/11—Ground squirrel
20	N.A.	5/11	A	10			5/12—Ground squirrel
21	7E	5/11	B	8?			? —House cat
22	N.A.	5/14	D	2			5/15?—Ground squirrel
23	6	5/13	B	12			5/15?—Ground squirrel
24	5	5/14	F	(16)			5/17 and 21—Ground squirrel
25	6	5/14	F	6			5/15?—Ground squirrel
26	6	5/14	A	(15)			5/22?—Coyote
27	5	5/13	C	(18)			5/18—Ground squirrel
28	5	5/13	A	(15)			
29	Near 11	5/12	A	(15)	6/18	13	5/20—Trampled by horse
29a	Near 11	5/25	C	(13)			5/25—Robbed for experi- ment
30	1	5/17	G	8			5/18?—Ground squirrel
31	1	5/17	D	10			5/25—Trampled by cow
32	6	5/19	F	(8)			5/20—Coyote
33	7E	5/20	B	?			? —Coyote
34	6	5/20	F	8			5/22?—Ground squirrel
35	6	5/20	D	5+			5/25—Ground squirrel
36	4	5/20	C	4			5/24—Ground squirrel
37	3	5/21	B				5/21—A.B.L. ²
38	3	5/21	C				5/21?—A.B.L. ²
39	3	5/21	A	3+			? —California jay
39a	3	5/21	A	?			? —California jay
40	4	5/21	C	15			5/22—Bobcat
41	H.P.	5/21	C	1			? —A.A.L. ²
42	1	5/22	A	(11)	5/30?	11	
43	H.P.	5/22	A	1			? —A.A.L. ²
44	4	5/22	A	?			? —Coyote
45	3	5/24	C	?			? —A.B.L. ²
46	7E	5/24	B	(12)	6/16	12	
47	H.P.	5/24	B	5+			? —Bobcat
48	7E	5/25	A	(2+)			? —Coyote
49	3	5/25	F	(10)	?	10	
50	2	5/26	A	(9)	6/18	9	
51	6	5/26	A	(9)	6/13	8	
52	4	5/26	A				? —A.B.L. ²
53	7W	5/26		?			? —Ground squirrel
54	6	5/28	C				? —A.B.L. ²
55	H.P.	6/1	C	5+			? —House cat
56	H.P.	6/1	C				? —A.B.L. ²
57	N.A.	6/1	A	(15)			6/4—Ground squirrel
58	5	6/3	I	(12)			6/8—Ground squirrel
59	6	6/4	A	?			? —Ground squirrel
60	5	6/4	D	(21)	6/10	18	
61	N.A.	6/7	D	?			? —Unknown
62	7E	6/8	B	(7)	6/13	7	
63	N.A.	6/9	A	(10)			6/23—Ground squirrel
64	H.P.	6/9	E	(12)			6/20—Unknown
65	H.P.	6/7	E	10+			? —House cat
66	7E	6/12	H	(9)	7/8	9	
67	2	6/14	G	(14)	6/22	14	
68	N.A.	6/16	A	?			? —House cat
69	5	6/16	B	?	?	?	
70	2	6/17	I	(9)	7/8	9	
71	5	6/17	D	(9)			6/23—Trampled by cow
72	7E	6/19	H	(13)	7/4	12	

TABLE 2—Continued

Valley Quail Nests on San Joaquin Experimental Range, 1937

Nest No.	Pas- ture No.	Date first seen	Located in cover type	Total eggs	Date of hatch	Number of young	Terminal date and cause of failure
73.....	1	6/25	J	(7)	-----	-----	7/6—Ground squirrel
74.....	6	6/28	A	(10)	-----	-----	7/26—Ground squirrel
75.....	6	6/28	E	?	-----	-----	6/28—Ground squirrel
76.....	8N	6/28	C	(19)	7/4	11	
77.....	N.A.	6/29	A	(10)	7/2	10	
78.....	7E	6/29	C	(1)	-----	-----	7/12—Ground squirrel
79.....	7E	6/29	E	(9)	-----	-----	7/17—Ground squirrel
80.....	8N	7/1	B	(8)	-----	-----	7/10—Fox
81.....	10S	6/24	E	9+	-----	-----	6/29—Construction
82.....	10S	7/6	E	(13)	-----	-----	7/10—Ground squirrel
83.....	10S	7/6	E	3+	-----	-----	7/6—Ground squirrel
84.....	N.A.	7/6	B	(3)	-----	-----	7/12—Ground squirrel
85.....	H.P.	7/9	E	6+	-----	-----	?—Skunk
86.....	H.P.	7/9	G	9	-----	-----	7/29—Skunk
87.....	12	7/12	K	7	-----	-----	7/14—A.A.L. ⁷
88.....	7E	7/16	D	14	-----	-----	?—Skunk
89.....	7E	7/16	D	1+	-----	-----	?—Trampled by cow
90.....	8S	7/16	B	(6)	7/12	6	
91.....	N.A.	7/21	A	?	-----	-----	?—Ground squirrel
92.....	H.P.	7/26	A	8+	-----	-----	?—Unknown
93.....	H.P.	7/26	A	3+	-----	-----	?—Unknown

Figures in the fifth column "total eggs", surrounded by parentheses, indicate that the set reached some stage of incubation.

Letters used in the "cover type" column refer to types explained in the text below.

A.B.L.—Abandoned before laying.

A.A.L.—Abandoned after laying.

¹ Made by cock while hen was in nearby trap; abandoned when hen escaped.

² Cause of abandonment unknown.

³ Abandoned because of disturbance by man.

⁴ Hen killed by Cooper's hawk.

⁵ Hen killed while constructing nest, by a house cat.

⁶ Abandoned because of rodent disturbance.

⁷ Abandoned because of automobile traffic.

Nesting Cover

Eleven different cover types were used. Following is a summary of these types and the numbers of nests found in each. (See Fig. 107.)

A. Dry grass or weeds; no other protection: 31 nests. The sites varied as to the amount of adjacent cover from those built in isolated clumps of grass or weeds surrounded by extensive areas of scant vegetation to others in large areas of rather tall, dense, dry grass. (See Fig. 103.)

B. Dry grass or weeds growing through fallen, dead brush: 19 nests. On some parts of the Range, there are many relics of *Ceanothus cuneatus* bushes destroyed by fire in 1929. These have for the most part fallen. This brush is very resistant to weathering and has remained in place to form the framework of small, though dense coverts used by birds and rodents. (See Fig. 105.)

C. Granite or quartz outcrops in dry situations: 13 nests. In addition to the main protection of rocks, some nests here had screens of scant vegetation.

D. Green vegetation in the bottoms of wet swales or close to streams: 10 nests. Spanish clover (*Lotus americanus*) and true clovers (*Trifolium* sp.) form the bulk of this vegetation.

E. Tarweed (*Hemizonia virgata*) and turkey mullein (*Eremocarpus setigerus*): 8 nests. These two weeds make most of their growth after other vegetation is dry, and remain green throughout the

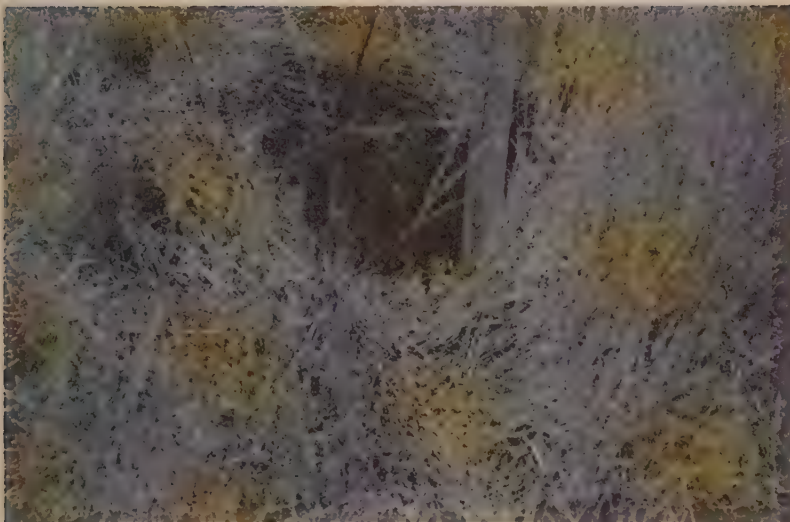


FIG. 103. Typical nest of valley quail in dry grass (No. 63, cover type "A"); later robbed by ground squirrel. (Compare Fig. 104.)

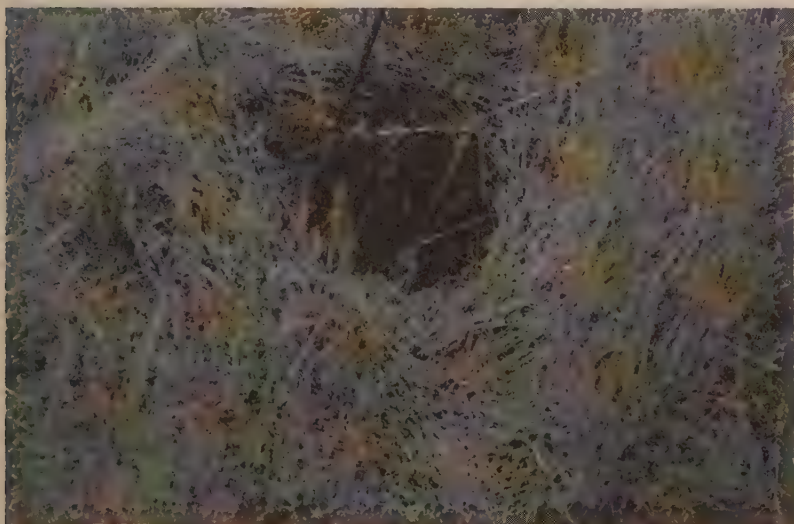


FIG. 104. Same nest as in figure 103 after being robbed by Beechey ground squirrel. Note lack of disturbance of either roof or lining.

rest of the summer. They grow in greatest abundance in swales wet during the early growing season.

F. Deerweed (*Lotus scoparius*): 6 nests. This is a low, dense shrub about one to two feet high, occurring in clumps on the more rugged parts of the Range.

G. Under live shrubs other than deerweed: 3 nests. These were respectively under a young *Ceanothus cuneatus*, a *Rhamnus californica*, and a small *Salix* sp. In view of the abundance of *Ceanothus* over the Range, it was surprising that other nests were not found associated with this shrub. The grass about the bases of this shrub on the Range is, however, fairly well eaten down by rabbits, and does not afford adequate nesting cover for quail.

H. Piles of scrap lumber: 2 nests.

I. Rocks close to running streams: 2 nests. This cover is really a combination of types C and D. (See Fig. 106.)

J. Niche or pocket in the bank of an eroded gully: 1 nest.

K. Straw pile: 1 nest. This nest was in rye straw scattered in a re-seeding attempt on the bank of a road cut.

Figure 107 shows also the numbers of nests, both successful and unsuccessful in each cover type. For some, the number of cases is too small to warrant any conclusions.

Nesting Habits

Eggs are deposited at the rate of approximately three every four days, varying with individual hens. The period between layings seems to be from 25 to 30 hours, judging from observations in about a dozen instances. As the hen is about to lay, both cock and hen go to the vicinity of the nest; the cock usually takes post in a nearby tree or tall shrub while the hen goes on the nest. A number of dropped eggs were found in the field.

During the period of incubation, approximately 22 days, the hen spends the hours from about 8 a.m. to 3:30 p.m. on the nest. She feeds with her mate from about sunrise to 8 o'clock and again, in the afternoon, she joins him from the hour indicated until about dusk, when she once more returns to the nest. Presumably she spends the night on the nest with the cock roosting nearby. The time spent on the nest by the hen is, however, not narrowly fixed but seems to vary according to the temperature of the day. On very hot days, the hen is prone to return to the nest earlier in the morning and to leave later in the afternoon.

While the hen is on the eggs, the cock takes post in some inconspicuous place in a tree or tall shrub, at an average of 25 or 30 yards from the nest, depending on the proximity of such cover. At intervals during the day, he gives low assembly calls and conversational notes. In late afternoon, these calls become more frequent, ceasing as the hen leaves the nest and flies to the tree in which her mate is perched. The pair then usually indulges in several minutes of "talking," after which they fly off to their feeding ground.

Sumner (1935, p. 202) has stated that cocks giving the explosive "cow" call are unmated. Experience on the Range, however, suggests that this note may be given by mated males. To quote from field notes of May 20, 1937, on nest No. 42:



FIG. 105. Typical open nest (No. 23, cover type "B") of valley quail in dry grass and weeds growing through dead and fallen brush. Such brush affords some mechanical protection to nests from grazing animals.



FIG. 106. Valley quail nest (No. 70, cover type "I") under a rock close to a stream. Once during incubation the stream was only three inches from the edge of the nest.

"3:25 p.m. Pair of birds seen to leave this spot (region of nest). Flew to north outside of rodent *exel*closure. Fed under blue oak. Cock flew up into blue oak and gave typical 'cow'—no other males about. Hen responded with assembly call and cock joined her."

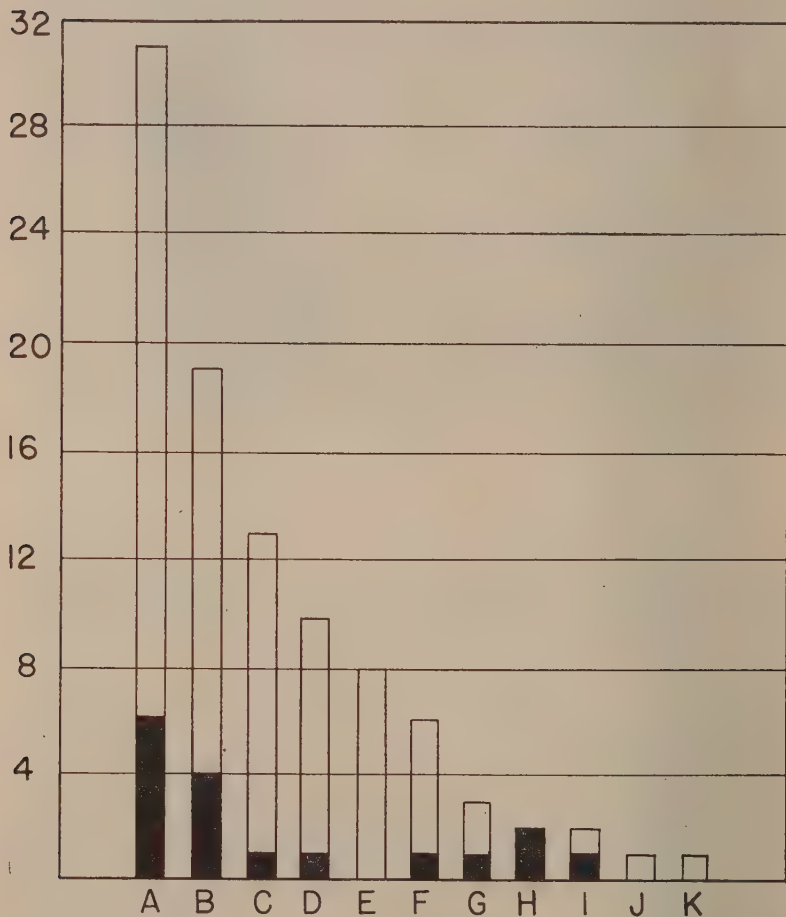


FIG. 107. Relative use of different cover types by valley quail in placing nests. Letters at bottom refer to cover types discussed in text (pp. 326-328). Black bars indicate successful nests; open bars, unsuccessful nests.

The eggs of this pair had been incubated since about May 7. Several other observations of crowing by obviously mated males led the writer to believe that the "cow" call is made by cocks desiring female companionship and not solely by unmated cocks.

As already indicated, the male is ordinarily in the vicinity of the nest during the period of incubation but there is no record in this study of a nest being incubated by a cock.

In 40 nests on the Range that had reached the stage of incubation an average of 10.97 eggs per clutch (limits of 1 and 21) was found. Grinnell, Bryant and Storer (1918, pp. 522-524) give the average clutch for California valley quail as 14.6 in an aggregation of records from the whole range of this subspecies within the State.

A decline in clutch size is evident at the Range toward the end of the nesting season. Thus, in 26 nests, May 1 to June 15, the average clutch was 12.2 eggs; in 15 nests, June 16 to July 15, the average was 8.5. (See Fig. 108.)

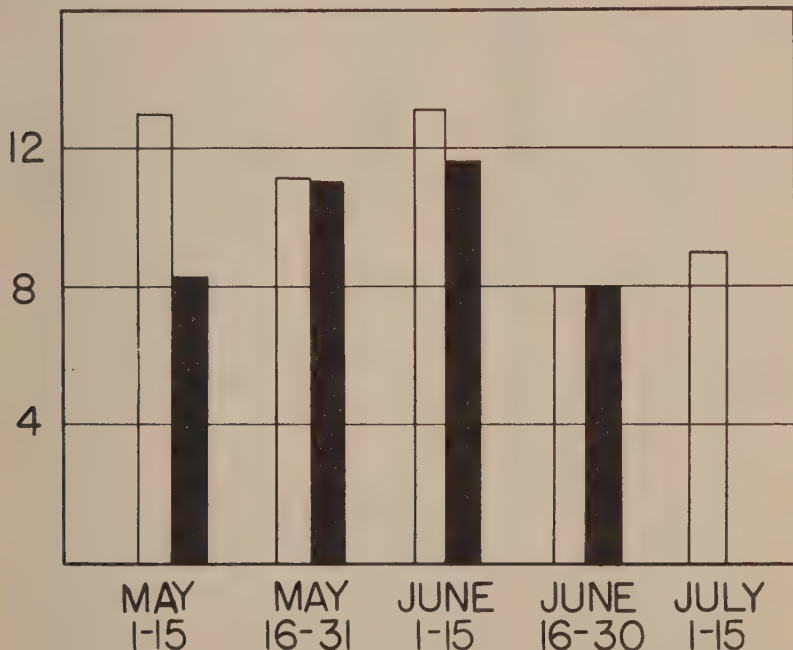


FIG. 108. Clutch size of all incubated nests and broods from successful nests of valley quail by semi-monthly periods in 1937. Open bar, average number of eggs; black bar, average number of young.

The number of nests in which incubation started in the several semimonthly periods, was as follows: May 1-15, 9 nests (3, or 33.3 per cent, successful); May 16-31, 10 nests (7, or 70 per cent, successful); June 1-15, 7 nests (4, or 57 per cent, successful); June 15-30, 8 nests (3, or 37 per cent, successful); and July 1-15, 7 nests (none successful). (See Fig. 109.)

The seasonal decline in percentage of successful nests and in clutch size, coupled with the premise that quail having a first attempt destroyed will renest, suggests that control of nesting predators, if undertaken, will give better results if done early in the season.

Hatching occurs about 22 days after the start of incubation as indicated by data from five successful nests where the date of start of incubation was known.

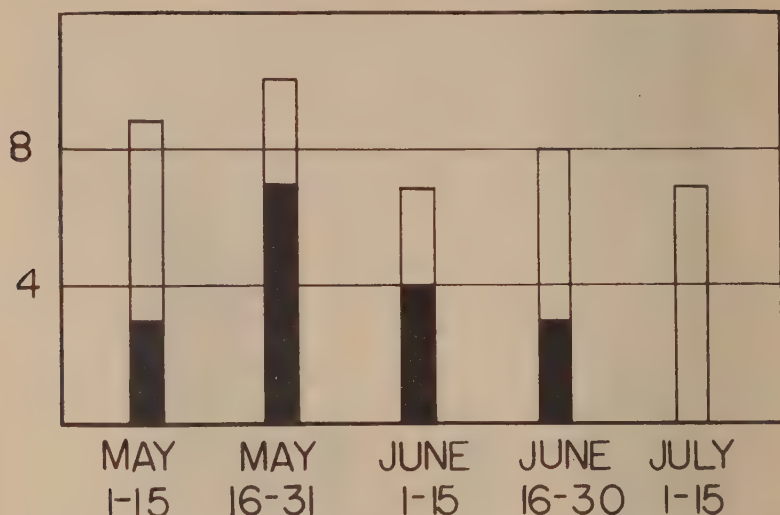


FIG. 109. Incubated and successful nests of valley quail in 1937. Black bar, successful nests; open bar, nests incubated, but not successful.

The behavior of the adults at hatching time may be illustrated by quoting from field notes on nest No. 2 of May 28, when the observer remained in a nearby blind throughout the day:

"8:45 a.m. Hen went on nest

"1:30 p.m. Hen still on nest

"2:00 p.m. Hen cast shell from nest

"2:20 p.m. More bits of shell cast out of nest by hen

"2:45 p.m. More bits of shell cast out of nest by hen

"3:45 p.m. Hen flew about 30 feet from the nest and walked back, calling as she came, uttering low, clucking notes. She was joined by four chicks. Group started feeding near nest. Male sat in blue oak over blind until hen and chicks got to taller grass about 150 feet away and then joined them.

"4:30 p.m. Observer left blind. Three eggs were left in the nest, making the total of seven recorded for the clutch. These three were later opened and found to be rotten."

The average number of young hatched in 16 nests throughout the season was 10.18 per nest (limits of 4 and 18). Evidence for these figures was derived by counting the number of pipped shells or by subtracting the number of unhatched eggs left from the known total clutch. For those in which incubation started during the first half of May, the brood averaged 8.3 birds per successful nest. Those in which brooding commenced in the latter half of May had a mean brood of 11.1. For the first half of June, the corresponding figure was 11.7 young, and for the latter half of June, 8.3 young per brood.

None of the nests in which incubation started in the month of July was successful.

Fate of Nests

In the total of 96 nests entered in table 2, every one happened upon is included, from those in the earliest recognizable stages of construction to those first seen when no longer attended by birds, by reason of abandonment, destruction or hatching. Due to the obvious impossibility of being present at all of the nests all of the time, it was necessary to establish criteria for determining the fate of those destroyed or hatched during the absence of an observer. (See Fig. 110.)

Successful

Successful nests were identified by finding egg shells showing the typical pipping ring. Young quail, like most birds, cut a neat ring about the larger end of the shell, leaving a cap that is either thrown off entirely or left hinged to the remainder of the shell by a bit of the shell membrane. A majority of the shells remaining in a successful nest will show a definite pip ring; some, however, are broken into small bits, evidently by the hen pecking at them after the young have emerged.

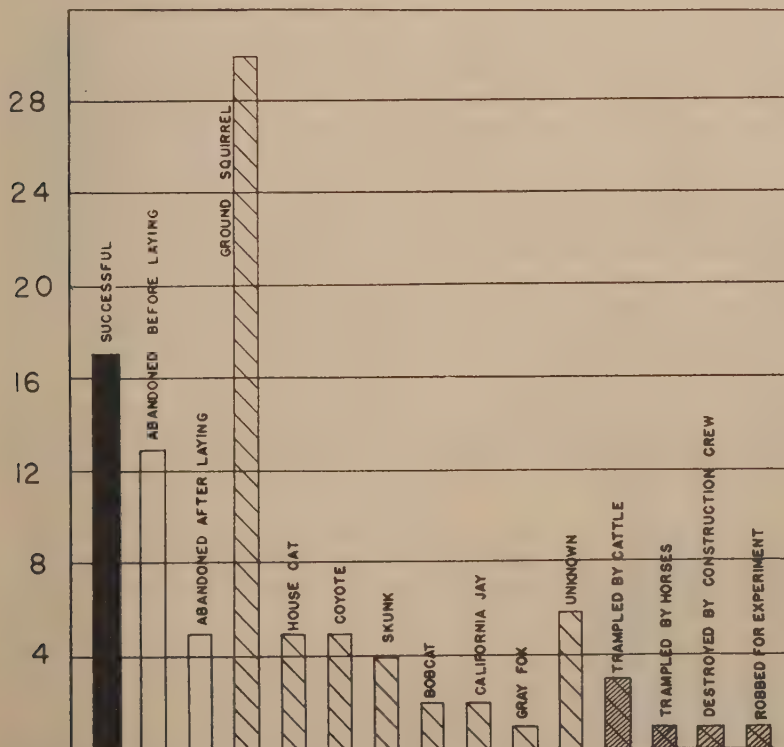


FIG. 110. Fate of 96 valley quail nests at San Joaquin Experimental Range in 1937.

Seventeen of the total nests found in the course of the 1937 study were successful. This figure can not be considered as a reliable index of the percentage of successful nests in the foothill region as a whole. It is recognized that nesting studies even at best are liable to introduce additional factors not present in the strictly unmolested natural condition. In addition, the possibility that pairs unsuccessful at first will make additional attempts at nesting, as suggested above, some of which might be successful, would make the percentage of pairs eventually producing broods greater than the figure cited above. This point has been considered in detail in respect to the ring-necked pheasant in the Midwest by Errington and Hamerstrom (1937).

Abandoned

Nests listed as abandoned before laying were those where birds had been observed in the process of nest building, but not attended by quail on later visits by the observer. Only two nests, Nos. 2 and 83, observed during the process of construction were later found to have eggs deposited in them. Quail seem to exhibit practically no sense of nest ownership until eggs have been laid. During construction, a pair will abandon the nest at the slightest disturbance, but show increasing reluctance to do so as the number of eggs in the clutch mounts, as indicated beyond.

Thirteen nests were abandoned before eggs had been deposited in them. This figure in itself is probably not significant for two reasons: first, the short period in which it is possible to observe such nests indicates that in all probability there are relatively more abandoned nests than were actually found; and second, the observer's presence is undoubtedly a factor in causing abandonment, which fact alone would make the observed percentage too high.

Abandonment of a nesting site before eggs are laid is not considered to be serious, since another site will probably be chosen in which to deposit the eggs. This type of nesting failure is here included merely for completeness of record and to show the presence of this trait among quail.

Five nests were abandoned after eggs had been deposited. Three of these (Nos. 16, 41 and 43) contained only one egg each. Nest No. 8, which had contained eight eggs, was left unattended after the hen had been killed by a Cooper's hawk. The fifth nest, No. 87, with seven eggs was presumably abandoned because it was located too close to a well traveled motor road.

TABLE 3
Summary of the Causes of Nest Abandonment

Abandoned before laying		Abandoned after laying		
Cause assigned	No. of cases	Cause assigned	No. of cases	No. of eggs
Disturbance by man.....	7	Hen killed by Cooper's hawk.....	1	8
House cat.....	1	Automobile traffic.....	1	7
Disturbance by rodent.....	1	Unknown.....	3	1 each
Cock's nest (mate died).....	1			
Unknown.....	3			
Total.....	13	Total.....	5	

Destroyed by predators

In attempting to determine what species of animal is responsible for destruction of a nest, where this occurs in the absence of an observer, reliance must be placed on "sign" in the form of droppings, hair, tracks or characteristic manner of nest destruction and egg eating.

Beechey ground squirrel--Perhaps the most difficult predator on which to obtain evidence is the Beechey ground squirrel (*Citellus beecheyi beecheyi*), most serious of all nest destroyers in the foothill regions. The evidence against the ground squirrel may be listed under several categories.

Early in the season a number of nests were found to have been neatly robbed by some small predator that left no definite "sign." Because of the abundance of ground squirrels (estimated population of 10 per acre) on the Range and the verbal suggestion by E. E. Horn that these animals elsewhere had been considered to play an important role with quail, it was deemed desirable to set up some experiment to determine the part the ground squirrel might play in respect to quail nests. (Gorsuch, 1934, pp. 68-69.)

Accordingly, on May 3, 1937, seven valley quail eggs taken from a nest, the hen of which had been killed by a Cooper's hawk, were placed in a man-made nest in a half-acre permanently fenced ground squirrel enclosure. Boiled canvas gloves were used to handle the eggs and to make the nest in an effort to avoid contamination with human scent; the observer's feet came no closer than 30 inches to the "nest". The "nest" was located in a natural setting, about 10 yards from the main burrow of the ground squirrels resident in the enclosure. It was roofed with a standing clump of red brome (*Bromus rubens*) and lined with red brome and soft-chess brome. At 1 p.m. the eggs were placed in the nest. The whole enclosure had been recently gone over by men taking plant samples, so that any chance that the rodents would track the observer to the immediate spot was slight. The nest was then observed from a blind until 2:30 p.m., during which time only two squirrels were noted to come out of the burrows. At this time, they did not forage about. At 4:30 p.m. the observer returned and found that the nest had been neatly robbed. The improvised roof and lining were entirely undisturbed.

The next day, a quail egg was found cast up on the earth about the opening of one of the squirrel burrows. Examination on succeeding days revealed many small pieces of shells cast up about the mouths of the burrows, sufficient to represent four eggs.

The experiment was repeated some weeks later, and a squirrel was seen to enter the artificial nest cautiously, grasp an egg with its incisor teeth, and run to its burrow. This was late in the day. Next morning the remaining eggs were gone. In this case also the nest was undisturbed save for the removal of the eggs.

The counterpart of this performance under natural conditions was observed on nest No. 24 by John T. Emlen (Emlen and Glading, 1938). This nest was farther from the squirrel's burrow than the experimental one, which may account for the difference in behavior in that the squirrel retired only a short distance from the nest to eat the egg, instead of taking it to the burrow. This nest was attended

by an incubating hen, but such was not the case in the experimental nest.

The evidence obtained from the experimental nests and from Emlen's observation led to ascribing robberies without significant signs of disturbance to *Citellus b. beecheyi*. The conclusion is tentative since it is possible that snakes or other animals may have been responsible for some of these robberies. Snakes known to steal eggs are relatively scarce on the Range, and certain nests were robbed in short order, so it is felt that snakes can be only a minor factor locally in this type of predation. The only snakes present which are potential nest robbers are the gopher snake (*Pituophis catenifer heermanni*), the king snake (*Lampropeltis getulus boylii*) and the striped racer (*Coluber lateralis*), all of which are relatively uncommon locally. That the Pacific rattlesnake (*Crotalus viridis oreganus*) does not regularly include quail eggs in its diet is illustrated by an instance connected with nest No. 80. A rattlesnake was found resting in the nest on the full clutch of eggs. When first seen, the snake was relaxed as if sleeping. It was killed, in the supposition that it had had a full meal of eggs, but the stomach was entirely empty. Bent (1932) reports a parallel case with the scaled quail that is commented on by Gorsuch (1934). In view of all these considerations, nests that were neatly plundered, with the lining and roof left intact, were ascribed to the ground squirrel. In a few cases, this diagnosis was at least partially substantiated by the finding of quail egg shells at nearby ground squirrel workings or on lookout rocks used by the squirrels.

Further evidence against the ground squirrel as an important nest destroyer was the finding of quail egg shells about the mouths of squirrel burrows in the field in five different places apart from any quail nests here recorded. In yet another place an egg shell of the western mourning dove was discovered on a squirrel's "door-step."

Thirty (31.25 per cent) of the 96 nests seen in 1937 were considered to have been raided by this predator.

Evidence of a different sort, to support the contention that this ground squirrel is a major predator of quail nests, was obtained in rodent exclosures at the Range. These exclosures are each 50 feet by 50 feet and are surrounded with a 3-foot hardware cloth fence, topped by a galvanized sheet metal overhang; they are used to help determine the effect of rodents on the foothill ranges and are practically squirrel-proof. The plant cover within these exclosures is heavier, due to absence of cattle and rodents. This probably accounts for the apparent preference of quail for these sites. Eight of the 96 nests were found inside of such rodent exclosures, and of these, five nests were successful. Of the remaining three, one was abandoned before eggs were laid in it, and the other two were destroyed by California jays. The 62 per cent (5 out of 8) success within these plots compared with the 13 per cent (12 out of 89) success on the balance of the Range supports the contention that rodents affect the nesting success in quail.

Additional evidence on the relation of ground squirrels to quail was obtained from the results of a small rodent control campaign carried on in the headquarters area (HQ)—about 300 acres—to reduce the squirrels as a public health measure. This area was treated with strychnine-coated barley during May, 1936, and again in May, 1937.

Censuses of quail here were taken both before and after control was applied. In February, 1936, 90 quail were counted in 3 coveys. In February, 1937, 9 months after the first application of poison, 229 quail were recorded. In August, 1937, after the second poisoning, 420 birds were seen.

In a second area of approximately 350 acres (adjacent to the poisoned area but not so treated) the February, 1936 census was 90 birds; that of February, 1937 was 135 birds; and that of August, 1937, 299 birds. By way of comparison, the original 3600 acres of the Range had 1662 quail in February, 1936, and 2123 in February, 1937, an increase of 29 per cent. The 350 acres not poisoned showed a 50 per cent increase for the same period, whereas the poisoned area had an increase of 154 per cent! Increased population in the non-poisoned "control" area may have been due to overflow from the poisoned area adjacent.

A census in March, 1938, gave 1545 quail on the 3600 acres of the original Range, 90 on the control area, and 220 for the poisoned area. (See Table 4.)

TABLE 4
Comparisons of Quail Populations on Poisoned and Non-Poisoned Lands

	February, 1936		February, 1937		August, 1937		March, 1938	
	Poisoned area	Control area	Poisoned area	Control area	Poisoned area	Control area	Poisoned area	Control area
Quail.....	90	90	229	135	420	299	220	90

Future plans call for a more extensive study of the importance of ground squirrels as nest predators and on the use of ground squirrel poisoning as a game management tool.

House cat—House cats have been responsible for a number of nest failures. They have a fairly characteristic way of cracking the eggs and removing the contents. (Compare Stoddard, 1931, p. 190, pl. 36.) The egg shells are crushed into two or three pieces and the contents are licked out. Shells are found mostly within two or three feet of the nest. The nest is usually torn up to some extent and often the remains of the incubating hen are to be found nearby, with feathers scattered in a characteristic fashion. Instances of house cat destruction can usually be substantiated by finding tracks of these animals about the nests.

Feral house cats accounted for five of the nest failures. Observations made during the investigation indicate that the wild house cat is an abundant and bothersome pest locally, even in areas distant from human habitation. An instance illustrating the abundance of wild house cats on the Range was obtained in an effort to get rid of cats around headquarters. A group of seven house cats was harbored by a cat enthusiast in the Civilian Conservation Corps camp. It was decided to trap and kill these "subrosa." An intensive campaign was carried on, and in about a week seven cats were killed. An investigator surreptitiously looked into the original source and to his consternation found seven cats alive and healthy!

Coyote—Nests that had been roughly destroyed, with small bits of well-chewed eggs scattered about, were attributed to the coyote. This type of damage is very similar to that described by Stoddard for dogs. Roaming dogs are not common on the Range, and some of the coyote diagnoses were verified by tracks, so that all nests found so destroyed were attributed to the coyote.

Five losses were ascribed to coyotes.

Skunk—The egg-eating habits of skunks are very well outlined by Stoddard. Several nests at the Range were found that exhibited every detail of destruction as outlined by Stoddard (1931, p. 186, pl. 35, fig. 2). The shells are for the most part merely smashed in on one side and have the contents neatly licked out; the relics are left in or near the nest. The hen may or may not be killed. (See Fig. 111.)

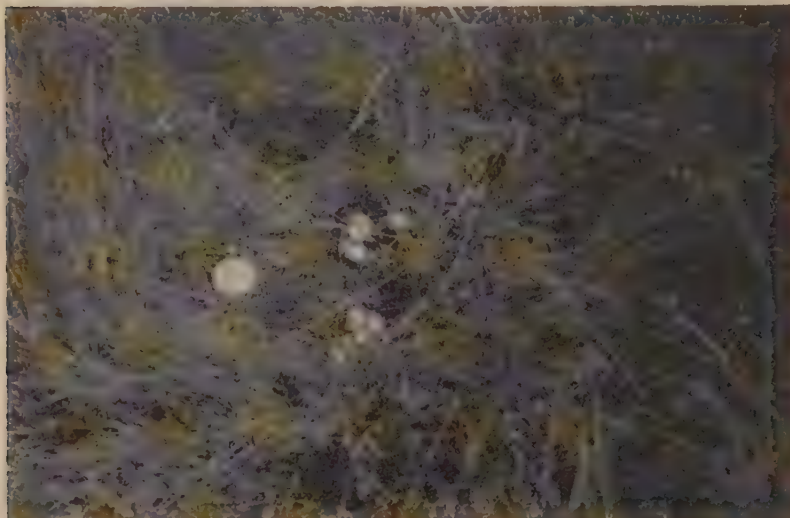


Fig. 111. Nest (No. 14) of valley quail robbed by skunk. Each egg is crushed in on one side and the contents sucked out; the shell is usually in one piece. Feathers of the killed hen are in the background.

Skunks were responsible for four (4.16 per cent) nest robberies and the death of one hen.

Bobcat—The bobcat destroys a nest in much the same manner as the house cat, only it scatters nesting materials about more widely. Two nests were lost to bobcats, tracks being found in the vicinity of both.

Gray fox—The gray fox has been a suspect in the matter of nest robbing. Thought to be typical of fox work was nest No. 80, which was destroyed on July 10. To quote from field notes of that day:

"7-10-37. 10:00 a.m. Nest visited—found robbed, not badly disturbed, but lining partly scattered and some small shell fragments

scattered about * * *. A few small, dog-like tracks [these were later checked and found to be fox] were found in the dust around the nest * * *. The fact that no quail feathers were found indicated that the hen probably flushed, and did not put up a struggle, nor was she killed."

Nest No. 80 was the only one definitely attributed to the gray fox, but it is felt that some of the earlier nests listed as "destroyed—predator unknown" could possibly have been lost to the gray fox. Foxes are fairly abundant on the Range and in the vicinity. Field workers report them frequently from various parts of the Range, and it is not uncommon to see them at night while driving along little used motor roads.

California jay—Destruction by the California jay was diagnosed by finding bill marks on the egg shells. These shells still contained some of the yolk and white, in contrast to those destroyed by mammals, which were licked clean. Two robberies blamed on the jay were of nests located within a rodent enclosure.

Two nests (Nos. 39 and 39a) about five yards apart, presumed to be successive nests of the same pair, were robbed by the California jay. Since the jay has such a characteristic manner of destroying nests, it is certain that additional predation by this bird was not overlooked in the study.

Unknown predators—Six nests were destroyed by unknown predators, all presumably mammals, judging from "sign" found at the nests. These nests probably could all be ascribed to cats, dogs, coyotes, foxes, bobcats, or raccoons, but the evidence was inadequate for positive identification.

Miscellaneous Losses

Six nests were listed as destroyed accidentally or otherwise. Instances of destruction by cattle and horses were identified by tracks of the animals up to and on the nest. Nests in this category contained merely an "omelet" of smashed quail eggs. Three were trampled by cattle. It is significant that all of these were in patches of green vegetation in swales or by streams (cover type "D"), places frequented by cattle in search of succulent vegetation on an otherwise arid range. No correlation was found between intensity of grazing and destruction of nests by cattle. It is believed that nests located in this succulent forage are always in danger of being trampled due to the thoroughness with which these places are grazed, regardless of the intensity of grazing over a pasture as a whole.

One nest, No. 29, was trampled by a horse, and while only a few eggs were smashed, the hen abandoned the nest.

A construction crew inadvertently threw dirt on nest No. 81.

Nest No. 29a from without the Range was robbed to supply eggs for the second experimental nest used in the rodent enclosure. It was not located on the Range proper, and is here included only for completeness of record in compiling cover, size of clutch and other data.

Summary and Conclusions

1. The nesting cycle of the valley quail in the foothills of the Sierra Nevada is considered to be an important phase of the game management problem of this species in California.

2. In a study on the San Joaquin Experimental Range of the U. S. Forest Service in Madera County, California, during 1937, a total of 96 nests of valley quail was found.

3. Courtship and nesting behavior are outlined.

4. The maximum number of nests was found in the month of May.

5. The average clutch size in 40 incubated nests was 10.97 eggs. The average brood size in 16 hatched nests was 10.18 young.

6. A wide range was exhibited as to choice of nesting cover, with dry grass being used most commonly, both as cover and as lining for the nests.

7. Methods of identifying the work of nest predators are given.

8. Seventeen of the 96 nests were successful.

9. Ground squirrels are inferred to have robbed 30 of the 96 nests.

10. An increase of quail has followed reduction of ground squirrels by poison on a 300-acre area for two years.

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EIGHTH ANNUAL BLACK BRANT CENSUS IN CALIFORNIA¹

By JAMES MOFFITT

California Academy of Sciences

Due to the writer's absence in the East, the 1938 black brant (*Branta bernicla nigricans*) census was supervised by Dr. R. T. Orr, Assistant Curator of Birds and Mammals, California Academy of Sciences. Dr. Orr counted the birds on Tomales Bay and the usual cooperators, mentioned beyond, at other points. Violent storms at census taking time in some cases considerably complicated securing accurate counts. Nevertheless, all save the Tomales Bay one are judged to be complete and as satisfactory as conditions permitted. Special thanks are due the cooperators this year for venturing forth in such disagreeable weather.

Humboldt Bay

Captain J. D. Dondero of the California Division of Fish and Game counted the brant on Humboldt Bay from car, foot and row boat, February 10, 1938. He secured a fair census totaling 45,000 birds. Some local residents then claimed more brant and ducks present than for many years. The brant were still arriving at Humboldt Bay at census taking time. Captain Dondero advised that at 6 p.m., February 13, when at the lighthouse, he saw two flocks of about 500 birds come from the south and alight on South Humboldt Bay.

Later, under date of March 13, 1938, Captain Dondero made the following report:

"More than 100,000 black sea brant on Humboldt Bay. Feed must be getting short as these birds are going out in the open fields feeding on green grasses, something that the old timers say they have never seen the brant do before."

Bodega Bay

Due to the absence of Dr. J. M. Linsdale, usual cooperator for this area, Game Warden Bert Laws counted the brant on Bodega Bay (Lagoon) from 10:30 a.m. to noon, February 12, 1938. The tide was falling (high, 8:43 a.m., 6.2 ft.; low, 3:41 p.m., — 0.7 ft.) and the Bay was choppy from a fresh southwest wind. Brant were found scattered over the open water except in the southeast corner of the Bay where 425 were on shore. Counting from land with binoculars, Laws totaled 1475 brant.

Tomales Bay

Dr. Orr's report of the census made by him at this Bay, February 12, 1938, is quoted below. Tides on Tomales Bay were essentially the same as noted above for Bodega Bay.

¹ Submitted for publication, August, 1938.

"Arrived at Pt. Reyes Station about 8:55 a.m. The day was exceedingly stormy with heavy rain falling in the lowlands and snow on Mt. Tamalpais. High tide around 9:00 a.m. No brant were seen until I was midway between Marshall's and Hamlet, then a few were noted along shore. Close to Hamlet 20 were seen. Inspection of the Bay with a 20x telescope between successive downfalls of rain showed most of the brant to be one-half to one mile north of Hog Island. Large numbers were seen moving about, mixed in with thousands of cormorants, ducks and gulls. Weather conditions and the tendency of the birds to move about made any count impossible so I waited until afternoon and low tide. By 1:00 p.m. the brant began concentrating just north of Hog Island and by 1:30 p.m. it was possible to take a count because the majority of the brant were in a long line stretching from just north of Hog Island to a point about one and one-half miles north. Several counts showed approximately 2600 brant in the one raft. They were fairly easy to count, even though far away, because there were practically no cormorants or scoters mixed with them. This group gradually moved south on the west side of the island, came around the south side of the latter and then worked north on the east side. There were probably several hundred more that were overlooked. At this same time a group of 273 was seen feeding on the mud flats between Hamlet and Preston Point. About one dozen individuals were also seen close to shore just south of Hamlet. It was impossible to determine what brant, if any, were present between Tom's Point and the ocean, as 17 days of rain had made it impossible to use any of the dirt roads leading west from the highway to the Bay. In all about 3085 black brant were estimated to be in the Bay south of Tom's Point."

Drake's Bay

Game Warden R. J. Yates took the brant census on this Bay, also known as Limantour Bay and Drake's Estero, February 12, 1938. Tidal and weather conditions were similar to those reported for Bodega and Tomales bays. He concluded 3500 brant were present and commented as follows:

"The storm had driven the birds all to the upper end, there being less than one hundred birds at the mouth of the Bay, so I feel that this estimate is very close as it is seldom that we can find the birds in one area."

Morro Bay

Game Warden F. W. Hecker and Dr. A. P. Marshall undertook the annual brant census at Morro Bay on February 12, 1938. The tides were: high, 8:35 a.m., 6.4 ft.; low, 3:38 p.m.,—0.5 ft. Mr. Hecker's report is quoted as follows:

"This year's brant census was made by Dr. A. P. Marshall and myself, and due to the position of the birds at the time it was necessary to make the count from shore. The greater part of the birds were feeding in the salt-grass flats within the boundaries of the State Park refuge. This is the first time that either of us ever saw any number of brant in that area or saw any of them feeding in the salt grass. This may be due to the fact that the flats were recently flooded by heavy storms. We were unable to determine what they were feeding upon.

"The total count was 5738 brant. Two weeks ago there were conservatively 10,000 brant on the Bay, but about half of them left during the heavy storms earlier in the week.

"During the time we were counting the brant we saw a duck hawk strike and bring down a brant in flight, either breaking or cutting its right wing so badly that it was unable to fly. This is the largest bird we have ever seen a duck hawk bring down."

Mission and San Diego Bays

Game Warden E. H. Glidden's report is quoted for this area. Mr. L. M. Huey, who for the sixth time cooperated this year, also provided a detailed report of the count, for which and his continued interest in the censuses, special thanks are due. Mr. Glidden's account follows:

"February 12, 1938, assisted by Mr. L. M. Huey, San Diego Natural History Museum, and Mr. Earl Warren, President of local chapter of the Izaak Walton League, the brant census was taken on San Diego and Mission bays from 9:00 a.m. to 5:00 p.m. The tides on that date were: high at 7:12 a.m., 7.0 ft.; low, 2:07 p.m.,—1.6 ft. The count as follows by actual count:

San Diego Bay (Cottonseed Point)-----	397
Mission Bay east of Causeway-----	104
Mission Bay west of Causeway-----	221
Total -----	722

"Birds feeding on mud flats. Many birds in immature plumage.

"Believe increase of birds during past few years may be attributed to an earlier closed season and better food conditions as floods during 1927 deposited an untold amount of silt in bays, which covered many acres of their principal food (eel grass) which is now coming up in sections formerly silted over.

"A preliminary census was taken on February 11, 1938, which disclosed 142 birds on San Diego Bay and 253 on Mission Bay. At that time visibility was exceptionally poor due to rain and winds.

"February 12 saw clear skies with exceptionally good visibility."

TABLE 1

Recapitulation of the California Black Brant Census, 1931-1938

Locality	1931	1932	1933	1934	1935	1936	1937	1938
Humboldt Bay-----	Unsatisfactory	29,415	5,000	16,860	115,000	50,000	22,500	45,000
Bodega Bay-----	None made	3,200	977	1,298	3,700	350	1,500	1,475
Tombes Bay-----	9,445	6,285	7,409	5,565	6,850	9,175	1,556	3,085
Drakes Bay-----	None made	2,108	318	2,189	1,995	1,500	1,500	3,500
Morro Bay-----	4,493	2,938	None made	3,895	7,544	5,000	5,331	5,738
Mission Bay-----	71	No birds	115	154	9	30	450	325
San Diego Bay-----	No birds	No birds	No birds	7	55	No birds	350	397
Totals-----	Incomplete	43,946	13,819	29,968	135,153	66,055	33,187	59,520

Remarks on the 1937-38 Brant Flight

As usual, maximum seasonal brant concentration was not reached on Humboldt Bay until about a month after census taking. This year seems to have been a "good" one for the birds there, the census

figure being exceeded only by counts of 1936, 1935 and the large, but unsatisfactory one of 1931. These occasional large assemblages of the birds on Humboldt Bay are difficult to reconcile with other factors. This season, counts elsewhere save Tomales Bay, where possibly all the birds present were not tallied, are about normal as has been the case in other years of heavy concentration on Humboldt Bay. It has been shown (California Fish and Game, vol. 21, 1935, p. 344) that large numbers of brant do not only occur in heavy winters, for that of 1930-31 was a light one. Furthermore, all data point to the fact that the brant that arrive at Humboldt Bay in numbers from January onward, come from the south (California Fish and Game, vol. 18, 1932, pp. 304, 306; vol. 21, 1935, p. 344), just as Captain Dondero reports them to have arrived on February 13 of this year. If bad weather were a factor accounting for large local concentrations, we would not expect them to be forced north by it in mid-February, yet this appears to be exactly what happens. The explanation appears to be that the birds first visit Lower California bays in autumn and leave them in mid-winter, probably as feed becomes depleted, then take advantage of southerly winds for their northward flights.

First arrivals of black brant at Tomales Bay in autumn have been recorded in previous census reports in *California Fish and Game* as follows:

1927, November 17, "several hundred" -----	(vol. 17, 1931, p. 397)
1931, November 8, 100 birds -----	(vol. 18, 1932, p. 305)
1932, November 16, 175 birds -----	(vol. 19, 1933, p. 259)
1933, October 19, "a few birds" -----	(vol. 20, 1934, p. 357)
1933, October 25, "several hundred" -----	(vol. 20, 1934, p. 357)
1936, November 15, "large numbers" -----	(vol. 23, 1937, p. 293)

Mr. Leonard Penhale, Department of Exhibits, California Academy of Sciences, happened to be at Tomales Bay on November 10, 1937, where he witnessed arrival of the first seasonal visitors. According to him, the birds came from the north in groups of about 50 each, commencing about noon and continuing through the afternoon until about 10 flocks or a total of 500 brant were present by evening. Local residents informed him that they were the first brant noted that autumn. The date appears to be about average for the locality, disregarding the exceptionally early flight of 1933. It should be noted that these birds came from the north, as it is believed do other autumn-arriving brant along the California coast. It is not until January that wintering flocks are augmented by returning migrants from the south.

Bodega, Tomales and Drake's bay populations should be considered collectively because of apparent interchange of brant. The 1938 total for the three bays, 8155, is nearly double the extremely low one of 4556 for 1937, yet behind the 1932-36 five-year average of 10,584. The aggregate population of these bays, also of other California ones save Humboldt, appears to run rather uniform from year to year. It suggests that the same birds, probably about all the food supplies can accommodate, return to the bays season after season. Occasional large concentrations on Humboldt Bay may be explained by the fact that it supports by far more brant food (eel grass) than do other California bays, that its usual quota of brant is below its carrying capacity, hence when feed becomes scarce elsewhere (Lower California, most likely) it is there that the birds come.

Brant seemed to linger in California later than usual in the spring of this year. Commander H. E. Parmenter (Gull, vol. 20, 1938, p. 27) recorded 175 birds present at Tomales Bay, May 18, and 500 on the 26th. He thought that the bulk of them left between then and June 1, when only 11 individuals were found. Eighteen were seen there on June 6. Several other reports reached me of observations of small flocks along our coast in mid-May. Two brant able to fly, thought to be laggard immatures, were found on Tomales Bay, July 21, 1938. The fact that these birds could fly indicates that the seasonal moult is late in this, as in other far northern breeding species of geese.

Attention is directed to Captain Dondero's remarks that in March brant were feeding on upland grasses about Humboldt Bay. His supposition that shortage of aquatic feed was the cause is probably correct. Mr. Hecker's report of the Morro Bay birds feeding in salt grass showed that the departure from normal habits was not confined to Humboldt Bay. J. E. Cushing, Jr., advised me that during the winter at Tomales Bay, brant were observed feeding on algae on mud flats at the head of the bay where they were theretofore unrecorded; also, that Mr. Nick Kojick of Blakes Landing, a reliable observer, had seen them feeding in grass fields in that vicinity. All these reports coming for the first time in one winter caused concern over the status of the brant's principal winter food, eel grass, and fear that the parasite that has wreaked such havoc among Atlantic Ocean *Zostera* and incidentally brant, may have reached the Pacific Coast. We were fortunate to have Dr. Clarence Cottam, in charge, Food Habits, Division of Wildlife Research, Bureau of Biological Survey, with us in July. He has been studying the disease of Atlantic Coast eel grass for several years. Dr. Cottam was so kind as to visit Tomales Bay with me on July 21, 1938, when we found the eel grass to be in excellent condition. Dr. Cottam considered it healthy indeed and could find no reason for concern.

Mr. Glidden's suggestion that reestablishment of eel grass in silted beds of San Diego Bay may in part account for the repopulation of the bay by brant is a likely one. The censuses show a gratifying increase in number of birds visiting the locality, though not quite so many this season as last. Both Mr. Glidden and Mr. Huey, in their separate reports, commented upon the large proportion of brant in immature plumage, seemingly indicative of a successful breeding season last summer.

A report of brant observed in Lower California, Mexico, waters in March, 1938, by D. H. Fry, Jr., is presented in the next article.

Summary

In point of total numbers, the 1938 census of black brant in California is about average for the eight seasons in which counts have been made. Humboldt, our most important brant bay, had more than usual numbers present at census-taking time and a tremendous concentration a month later. Here, the 1938 figures exactly doubled the previous year's, one of light visitation. The aggregate total for Bodega, Tomales and Drake's bays was somewhat under the 1932-36 average for the region, but an incomplete census was probably obtained at Tomales Bay this year and the deficiency might make up the differ-

ence. The Morro Bay 1938 result is close to counts obtained the previous two seasons, but twice as many birds were reported present two weeks before census taking. While somewhat lower than in 1937, the Mission-San Diego Bay aggregate of 722 brant indicates that numbers of the birds have become reestablished there after years of absence.

BRANT CENSUS OF SAN QUENTIN BAY, LOWER CALIFORNIA ¹

By DONALD H. FRY, JR.

California State Fisheries Laboratory

Division of Fish and Game

Early in the spring of 1938 the California Division of Fish and Game boat *Bluefin* made one of its many fisheries research trips into Lower California waters.

On March 20, bad weather forced us to run for cover and we anchored under Cape San Quentin. The following morning, it was still,



FIG. 112. Brant over the west arm of San Quentin Bay, Lower California. This scene is a typical one: rocky shoals, sand dunes near the shore, and a low flat, brushy coastal plain extending for miles. Photo by D. H. Fry, Jr., March 21, 1938.

quite rough outside, but San Quentin Lagoon was calm. This lagoon is a famous spot for brant and we decided that with the ocean as rough as it was the best use we could make of our time was to count the brant in the lagoon as a supplement to the census made annually in California by James Moffitt. (See pages 341-346.)

To carry out the plan, four of us crossed the bar in the outboard powered dinghy and went on up the channel into the lagoon. Few

¹ Submitted for publication, June, 1938.

brant were encountered until we neared the dividing of the channel. At this point there were many harbor seals, including some tiny pups. After some searching we found the channel going into the west arm

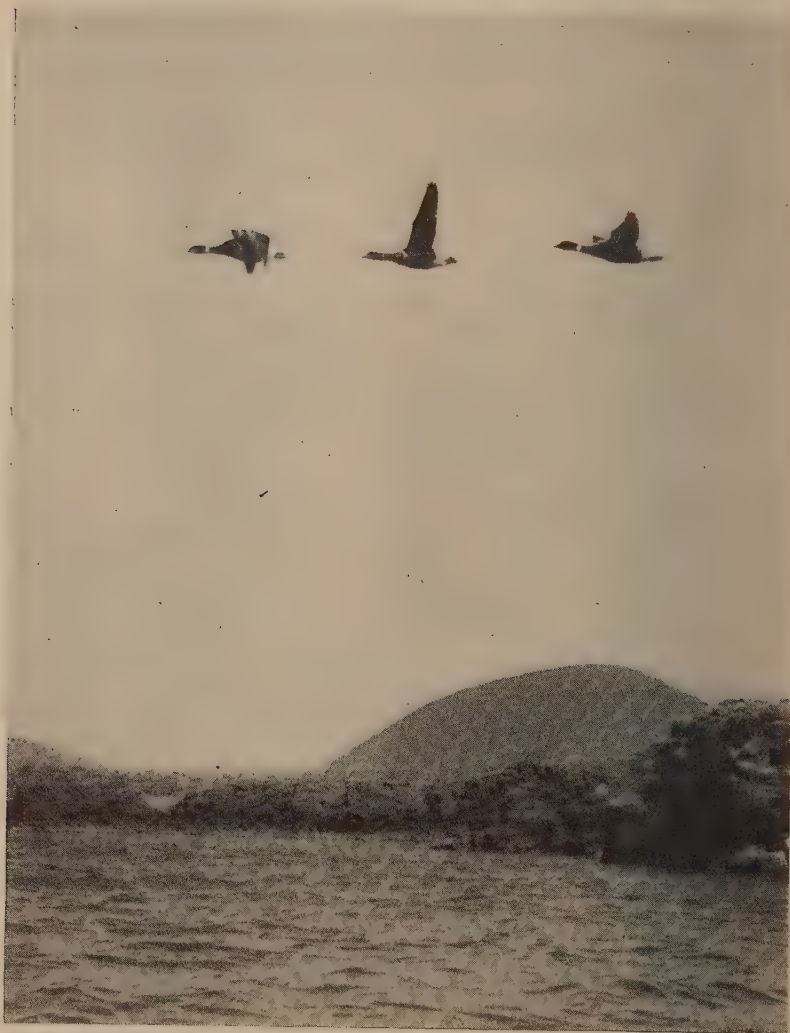


FIG. 113. More brant—try to get this close when you have a gun! West arm of San Quentin Bay. These low black cliffs are a somewhat less typical shore line (compare figure 112). The hay-stack-like hill in the background is one of several which serve as unmistakable landmarks for mariners. Photo by D. H. Fry, Jr., March 21, 1938.

of the lagoon and from then on birds were numerous. Making a reasonably accurate count was easier than we had hoped. The channel runs near the eastern edge of this arm and most of the brant were

on that side. As we approached, they would get up, fly a short distance, settle near the western shore and stay there. They did not do the thing we feared most, *i.e.*, move around so much that it would have been difficult to keep track of the flocks.

Taking a proper census of the eastern arm was not so easy. The wind had risen and was kicking up a nasty chop that tossed the boat around and made it hard to count the brant in a large flock. In addition most of the birds we stirred up would either fly ahead of us and settle among other flocks or circle past us and settle behind us on the far side of the arm. None of them flew very far but there was nothing orderly about the procedure, and an accurate count seemed impossible. So, we followed one shore line, chased all the birds over to the other and then returned, staying far enough from the flocks so we could count them without making them fly. This worked perfectly until we came to a wide spot where shoal water kept us from getting close enough to make more than a rough estimate of the number of birds in that area.

The census:

Ocean to dividing point of arms of lagoon (counted)-----	180
Western arm (counted)-----	850
Eastern arm above salt works (counted)-----	35
Eastern arm below salt works (counted 200, plus estimated 300)--	500
Total -----	1565

As to the accuracy of the census, taking everything into account, it seems to us that the error might have been as great as 250 birds plus or minus but was probably much less. This is allowing for birds which might have been overlooked near the shore line and birds which might have been counted twice in crossing from one arm of the lagoon to the other.

HUNTING SEASONS IN GERMANY¹

By TRACY I. STORER
College of Agriculture
University of California

WITH AN INTRODUCTORY NOTE BY DONALD H. FRY, JR.

During the early 1880s, my grandfather spent several years in Germany. As he had always hunted in the United States, it was only natural that he should do the same over there. Recently, one of his hunting licenses came to light. As a license it was hardly more than a curio, but the abstract of hunting seasons on its back should be of interest to any hunter. These seasons are shown in exactly the same way in which seasons are shown on our California game cards. It seemed quite desirable to publish a translation in *California Fish and Game*, but some of the terms used by German hunters are quite specialized and my German dictionary and I were unable to arrive at any very definite conclusions about the exact meaning of some of them. Finally, to get a trustworthy translation, the card was sent to Tracy I. Storer of the University of California, College of Agriculture, who has spent several years studying game conditions in Europe.

The following notes and translations are Dr. Storer's:

The accompanying translation of a hunting license for the Grand Duchy of Saxony-Weimar-Eisenach for 1881-82 makes available information as to the open seasons for hunting in that portion of Germany 57 years ago. It will be noted that the seasons on both resident and migratory species were long, in some degree comparing with seasons for hunting in those years in California (1880: ducks, September 15 to March 15; quail, September 15 to March 15; doves, June 1 to January 31). A translation of the Prussian Hunting Law of January 18, 1934, now the "national game code" for Germany, shows that for many species of game in that country long seasons still prevail. By comparison, in California the seasons are now much shortened (1934: ducks, October 1 to January 15 [federal regulations cut this to Saturdays and Sundays only from November 15 to December 31]; quail, November 1 to December 31; doves, September 1 to December 15 [or October 31].) Game in Germany has been carefully managed for many decades and shooting rights have been leased (as indicated in the footnote on the license.) Lessees have been required to conserve a breeding stock and "game hogs" were and are quickly dispossessed of hunting privileges.

The following table compares the shooting seasons for some common game animals of central Germany in 1881-82 and in 1934.

¹ Submitted for publication, July, 1938.

Some Hunting Seasons in Germany

	According to Hunting License of Grand Duchy of Saxony-Wei- mar-Eisenach 1881	According to Prussian Hunt- ing Law of Jan- uary 18, 1934
Red deer, males.....	July 1-Jan. 31	Aug. 16-Dec. 31
Females and calves.....	Sept. 1-Jan. 31	Oct. 16-Jan. 31
Fallow deer, males.....	July 1-Jan. 31	Sept. 1-Dec. 31
Females and calves.....	Sept. 1-Jan. 31	Oct. 16-Jan. 31
Roe deer, males.....	June 1-Jan. 31	June 1-Oct. 15
Females	Oct. 16-Dec. 14	Oct. 16-Dec. 31
Calves (female).....	none	Oct. 16-Dec. 31
Badger	Oct. 1-Nov. 30	Sept. 1-Dec. 31
Hares	Sept. 1-Jan. 31	Oct. 1-Jan. 15
Capercaillie and black game, males.....	Sept. 1-May 31	April 1-May 15
Females	Sept. 1-Jan. 31	none
Hazel grouse.....	Sept. 1-Jan. 31	Sept. 1-Nov. 30
Bustards, males.....	July 1-Apr. 30	Apr. 1-May 15
Pheasants, males	Sept. 1-May 31	Oct. 1-Jan. 15
		(exceptionally to Apr. 15)
Females	Sept. 1-Jan. 31	Oct. 1-Jan. 15
Partridges	Sept. 1-Nov. 30	Sept. 1-Nov. 30
Wild ducks	July 1-Mar. 31	July 16-Dec. 31
		(exceptionally to Jan. 31)



GRAND DUCHY OF SAXONY-WEIMAR-EISENACH

No. 358 HUNTING-LICENSE

for the bookseller Mr. Alb. Bancroft

residence at Weimar

valid from 24th Septbr 1881 until 24th Septbr 1882

Weimar the 24th Septbr 1881

The Grand [Duchy] S. [i.e. of Saxony] Director of the I Administrative District.

[Signature] [?] W. Henn

The licensee has always to carry this license upon his person while hunting and he has to show it upon demand of the holder of the hunting right, the holder of the [local] hunting lease, the hired guards, the communal president, the communal employees of the field and hunting police, as well as to the grand ducal gendarmerie or other police officials, on penalty of up to 15 M [arks fine].

Anyone who tries to use a license which is not issued in his name is fined from 15-150 M [arks].

Grand Duchy of Saxony-Weimar-Eisenach

Valid for one year.

Paid with 8 Marks [? \$2.00].

FIG. 114. Upper: reproduction of the face of a German hunting license issued in 1881. The original license is $5\frac{1}{2} \times 3\frac{1}{2}$ inches. Lower: the translation.

Grün = Jagdzeit. Schwarz = Schonzeit.	Januar.	Februar.	März.	April.	Mai.	Juni.	Juli.	August.	September.	Oktober.	November.	Dezember.
Männliches Roth- und Dammwild.												
Weibliches Roth- und Dammwild, Wildkälber												
Rehbücke												
Weibliches Rehwild. Dor 15. Oktober und 15. Dezember sind in der Schonzeit mit inbegriffen.										15. Okt.		15. Dec.
Rehkälber.												
Dachs.												
Auer-, Birk- und Fasanen-Hähne.												
Enten.												
Trappen, Schnepfen, wilde Schwäne etc. cf. § 1 N. 9.												
Rebhühner.												
Auer-, Birk- und Fasanen-Hennen, Haselwild, Wachteln, Lerchen, Hasen.												
Drosseln.												

Green (White in this translation) = Hunting Season Black = Closed Season	January	February	March	April	May	June	July	August	September	October	November	December
Male Red ¹ and Fallow Deer ²												
Female Red and Fallow Deer, Calves												
Roebucks ³												
Female Roe Deer The 15th of October and the 15th of December are included in the Closed Season										Oct. 15		Dec. 15
Roe Deer Calves												
Badger ⁴												
Capercaillie ⁵ —Black Game ⁶ —and Pheasant ⁷ Cocks												
Ducks												
Bustard ⁸ Snipe, Wild Swan etc cf. § 1 N. 9 (This probably refers to local game code)												
Partridges ⁹												
Capercaillie—Black Game and Pheasant Hens, Hazel Grouse ¹⁰ , Quail ¹¹ (Sky) Larks ¹² , Hares ¹³												
Thrushes ¹⁴												

FIG. 115. Upper: reproduction of the reverse of a German hunting license issued in 1881, showing open and closed seasons. Lower: translation. Footnote numbers refer to scientific names, as follows: ¹ *Cervus elaphus* (equivalent to elk in U. S.); ² *Cervus dama*; ³ *Capreolus capraea*; ⁴ *Meles meles*; ⁵ *Tetrao urogallus*; ⁶ *Lyurus tetrax*; ⁷ *Phasianus* sp.; ⁸ *Otis tarda*; ⁹ *Perdix* sp.; ¹⁰ *Tetrastes bonasia* (equivalent to ruffed grouse in U. S.); ¹¹ *Coturnix coturnix*; ¹² *Alauda arvensis*; ¹³ *Lepus* sp.; ¹⁴ Family Turdidae.

A STUDY OF THE TROUT (*Salmo irideus* Gibbons) FROM WADDELL CREEK, CALIFORNIA¹

By CEDRIC O. SNYDER

Introduction

This paper presents the results of an examination of an angler's catch of rainbow trout taken at intervals throughout the year in one of the smaller coastal streams of California.

The data used in this inquiry were obtained from upwards of one thousand trout caught by Mr. Theodore J. Hoover, Dean Emeritus of the School of Engineering, Stanford University. These fish were taken between May 1, 1927, and May 1, 1928, in Waddell Creek which flows through Mr. Hoover's Rancho del Oso. They were captured by fishing several times each month with the usual angling equipment consisting of rods, lines and lures. The data secured consisted of measurements of body length, weight in grams, a determination of sex, and scale samples from each fish. The scales were prepared and mounted by the usual methods employed for microscopic examination of fish scales. All were mounted in a Karo medium.²

Mr. Hoover's main purpose in collecting these fish and the attendant data was to determine if possible the age groups and their relative proportions in the catch—information not then available and yet very desirable in formulating plans for the conservation of the species.

That portion of Waddell Creek that flows through the Rancho del Oso has with the kindly interest of Mr. Hoover been the center of trout investigation for some years. A biological study of the stream valley was made by Merrill W. Brown (unpublished manuscript). A trout study was made by David Shepherd in 1929. He found that seven families of insects contribute largely to the trout food of this stream. These are: Rhyacophilidae, 2 species; Hydroptilidae, 1 species; Philopotamidae, 1 species; Odontoceridae, 1 species; Hydropsychidae, 1 species; Sericostomatidae, 4 species; Limnophilidae, 5 species. The stomachs of 55 fish were carefully examined. They contained 3703 organisms. Of these, 2135, or about 57 per cent, were insects in various stages of development. Larval stages were represented by 53 per cent of the entire stomach contents. Other animals than insects were arachnids, isopods, amphipods and nemathelminthes—all of these constituting about 42 per cent of the food. A further contribution to the food

¹ Submitted for publication, February, 1938. This article was abstracted from a paper presented as a thesis in partial fulfillment of the degree of Master of Arts at Stanford University.

Editor's note: Lest the reader be confused by the use of two different specific names for the rainbow trout, *S. irideus* and *S. gairdneri*, in recent articles appearing in *California Fish and Game*, we should like to call attention to the fact that there are two schools of thought on the subject, each favoring a different name. For the time being, individual authors may use whichever name they prefer.

² *Karo Korn Syrup* was adopted as a scale mounting medium by Dr. Willis H. Rich and his assistants in salmon studies because of its rather high refractive index and because it forms a lasting mount of the scale.

situation in Waddell Creek was made more recently (Needham, 1934). Fragments of small plants as pollen grains, etc. often form some of the stomach contents, but it is quite likely that these are ingested along with surface insects.

In general, it may be said that the trout food of a stream depends very largely upon the neighboring terrain and that when natural forest or grass land conditions are preserved, the stream will be found to contain a sufficient amount of food. When the forests and meadows have been destroyed by fire or by overgrazing, the food supply will be disturbed in a large measure.

In 1933 the California Trout Investigations, sponsored by the California Division of Fish and Game, the United States Bureau of Fisheries and Stanford University, with the cooperation of Mr. Hoover, established a weir in the stream for the purpose of observing migrations and other habits of fish.

The present study was made and the report prepared under the direction and with the aid of Professor Willis H. Rich of Stanford University.

The Rainbow Trout

From the point of view of most anglers, two species of trout occur in our coastal streams, namely, the "steelheads" and the "rainbows." The larger, more plainly colored migrant from the ocean is placed in the first category, whereas the smaller and more brilliantly colored stream trout is referred to by the latter name. Many ichthyologists were formerly of a like opinion, and the scientific literature of fishes then recognized the two forms as distinct species (Jordan and Evermann, 1896). At the same time, they did not recognize any marked anatomical differences between the two and they were unable to find the young of two distinct species in the same stream.

It is now established beyond doubt that both the so-called steelhead and rainbow are members of the same species, the steelhead being the adult individual which has lived for a time in the ocean, whereas the rainbow is the stream fish which has not yet migrated to the sea.

Recognition of the steelhead and rainbow as distinct species contributed in a measure to their depletion, as laws intended to protect and conserve them permitted an undue amount of fishing for both adults and young of the same species. Even now, some sportsmen are slow to recognize that killing a little stream trout means the death of a potential steelhead of several pounds.

As a matter of fact two distinct species of trout do occur in the more northern coastal streams of California, each with its stream and ocean form of population. One of these is the cut-throat trout, *Salmo clarkii*, akin to the species *S. henshawi* found in the waters of the eastern Sierran slopes and in Nevada. While plentiful in Oregon, Washington and to the northward, *S. clarkii* lives in only a few of the very northernmost streams of California, including Mad River in Humboldt County. In Redwood Creek, for example, one may find small cut-throat and rainbow trout, while large cut-throat steelheads and rainbow steelheads migrate in from the ocean. The State fish hatchery in that locality takes spawn from both, the hatcherymen having no difficulty in distinguishing them.

The rainbow trout, *Salmo irideus* Gibbons, the species here dealt with, inhabits the streams of the Pacific Coast wherever conditions permit. It enters the streams as a steelhead and migrates even to the uppermost tributaries to spawn, after which it usually returns to the ocean. The young of the steelhead remains in the stream an indefinite time, progressing with growth to deeper water, eventually to enter the sea and finally to become a steelhead like its parent.

The rainbow trout is a beautifully colored fish, although not to be compared with some of its more brilliant relatives as the golden trout of the High Sierras. Generally speaking, it exhibits three phases or variations of color while living in fresh water. The first of these may be called seasonal variation. It comes upon the fish as they approach maturity. The bright colors, particularly on the sides, become greatly intensified, whereas the background becomes darkened. The second is referred to as local variation. Fish found in deep pools or in dark or densely shaded water are invariably more somber in appearance than those found elsewhere. In boggy streams they often become a very dark brown-black, the color even extending to the ventral surfaces. In streams where the water is bright and sunny and where the fish are exposed to much light, they generally are much lighter in color. Here the upper surfaces have a great deal of yellow and the belly is light and silvery. The third is called geographic variation. Many observers, particularly sportsmen, speak of very noticeable varietal characteristics that are nearly always based upon color but which sometimes take into account body form. Some of these have been recognized by ichthyologists and given names. California fish hatcherymen frequently speak of such forms as the "Kosk Creek trout," the "Rising River trout," the "pogey" of Lake Tahoe, and others. This condition appears to be no different from that found in other species of fish, as well as in birds, and in mammals of wide distribution, particularly in the West.

Rainbow trout are semiboreal in their distribution, being found in streams where the water is clear, cool, and through its rapid flow, well aerated. Although such conditions are usually associated with the higher mountain systems such as the Sierra Nevada and the Siskiyou, the Coast Range offers comparable situations. The tributaries of the streams that rise in them have a slight snowfall during a portion of the winter months, are bordered by coniferous forests, and are cooled by frequent fogs throughout the warmer part of the year. Taken together, these factors aid in effecting a suitable temperature for the needs of growing trout.

Description of Waddell Creek

As previously noted, the fish with which the present study is concerned were taken in Waddell Creek. This creek is, like many others in the region, an almost perfect likeness of larger coastal streams; its mouth, its lagoon, its lower reaches, and finally its upper tributaries—all present in miniature the general characteristics of such rivers as the Eel and the Klamath.

Waddell Creek flows into the ocean a few miles south of Año Nuevo Point on the northwestern coast of Santa Cruz County. (See Fig. 116.) Rising in the Santa Cruz Mountains at an altitude of 1500

feet, it drops rapidly to sea level through the rather short distance of twelve miles. This drop results in numerous rapids and waterfalls which cause the current to be rather swift. Two main branches are formed by the juncture of a half dozen or so tributary creeks whose source is in the California Redwood Park (Big Basin). The branches,

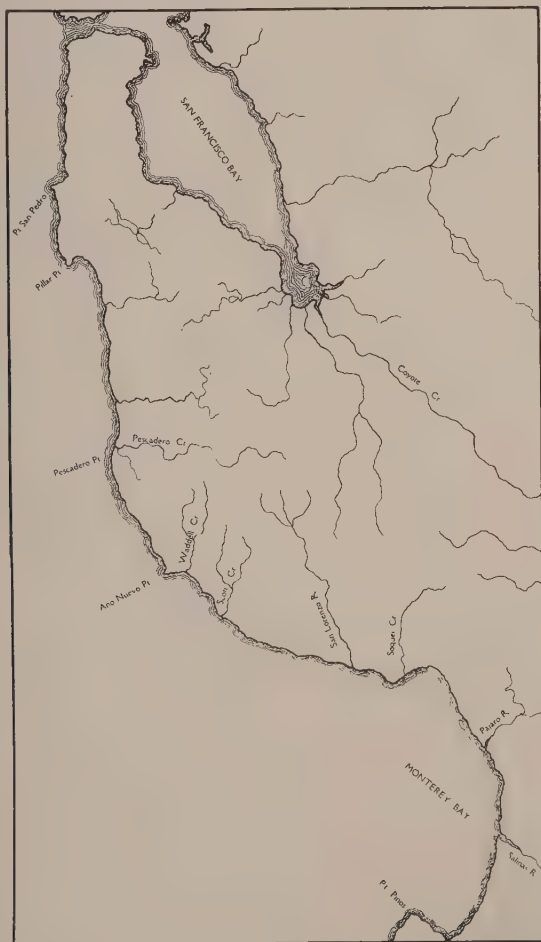


FIG. 116. Map showing relationship of Waddell Creek to the other streams between San Francisco and Monterey Bay.

called East and West, respectively, join to form the main stream. The lower portion of the stream presents a drowned mouth or lagoon which is intermittently closed by a shifting bar. During the high water of winter it is almost constantly open. Beginning with deep-cut gorges, characteristic of the tributaries and to a lesser extent of the branches whose banks start to recede, the valley of the main

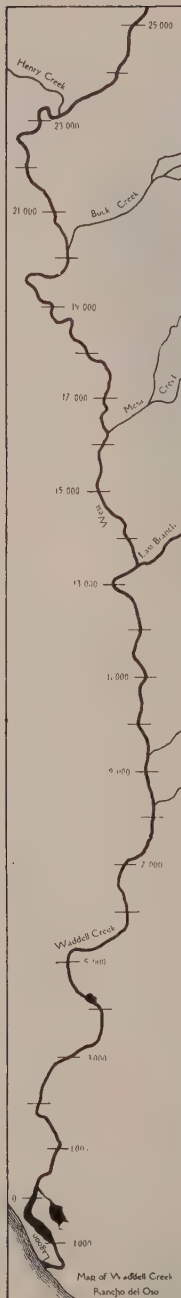


FIG. 117. Map of Waddell Creek. The figures represent distances in feet.

stream broadens out, forming numerous patches of cultivated grass lands, and finally the crop fields of Rancho del Oso. Transition coniferous forests composed of redwoods, firs and bays, are frequent along the bands of the upper reaches but recede toward the summits of the main stream valley. Upper Sonoran groves of buckeye, manzanita, madrone and chaparral comprise an intermediary growth of woody plants with islands of redwood and bay, extending nearly to the creek. Dense fogs spread over the creek during a portion of the year and to a certain extent affect the temperature of the water by cooling it. The flow is that of a perennial stream, although some of the tributaries which pass through the drier hillsides disappear during the summer and early fall, excepting for a few pools.

Fish Fauna of Waddell Creek

No strictly fluvial fish is to be found in Waddell Creek. In this respect, it conforms with other coastal streams from the Golden Gate to Monterey Bay. (See Fig. 116.) The species constituting the fish fauna of the stream are very limited in number. Bullheads (*Cottidae*) occur in varying abundance: *Cottus asper* and *C. aleuticus* are abundant and *C. gulosus* has been reported. The stickleback (*Gasterosteus cataphractus*) is more abundant in the lagoon and for a short distance up stream. In the lagoon itself are found certain salt-water forms as the striped bass (*Morone saxatilis*), the goby (*Gillichthys mirabilis*) and some flat fishes. The writer is not sure whether lampreys enter this creek as they do in many others.

The most important fishes found are the Salmonidae: the silver salmon (*Oncorhynchus kisutch*) and the rainbow trout (*Salmo irideus*). Silver salmon make regular migrations into the stream to spawn. The young of this fish grow very rapidly and are sometimes caught by anglers who mistake them for young rainbow trout. The exact ecological relations existing between any of these species or between any of them and the trout are scarcely known. It is reported that the cottoid fish feed upon the eggs and young of the trout when opportunity occurs.

The San Lorenzo, Pajaro and Salinas rivers, which enter Monterey Bay, have a fluvial fauna much like that of the Sacramento River (Snyder, 1913). In former years trout seemed to be just as abundant in these streams as in those where the fluvial fish were absent.

Depletion of Trout

Within the past forty years, the native trout have become greatly depleted, especially in the

coastal streams. These are easily accessible because of lack of deep snow in the winter and spring, and they are also near the centers of population from which most of them may be reached in a few hours' time over fine highways. One may readily appreciate the increasing scarcity of the fish in both size and number during this period by referring to early accounts of fishing conditions. One writer (Welch, 1929) says:

"Prior to 1905 and the enactment of a law fixing the daily creel limit at 50 trout, a catch of from 100 to 300 trout taken from the coastal streams by one fisherman during the day was not unusual. A catch of a dozen adult steelhead trout, or from 20 to 30 so-called 'grilse' (one- and two-pound steelhead trout) was not exceptional * * *. Between 1895 and 1905 fishermen who sold their fish frequently made catches of from 200 to 350 trout per day in the streams of Santa Cruz County * * *. In April, 1900, I saw 600 (four to ten inches) steelhead trout that had been taken on hook and line from Soquel Creek in Santa Cruz County, by one fisherman during one day * * *. I recall a catch of 618 trout and 21 adult steelhead trout taken on hook and line by four fishermen during one day in the lagoon at the mouth of San Gregorio Creek, in April, 1887. During the sixties, seventies and eighties, thousands of so-called 'grilse' or 'salmon trout' were caught by hook and line by fishermen fishing off 'Meiggs Wharf,' from the wharves all along the San Francisco water front and off the Oakland Mole."

While there can be no question of the serious depletion of rainbow trout, the exact causes of it are not so apparent. In the minds of many anglers, at least as they express it, depletion is not the result of their own sporting activities. They usually ascribe the principal ravages of the fish to three groups of animal predators: such mammals as the racoon, the mink and the marten; such birds as the merganser, the kingfisher and the water ouzel; and such other fish as the Sacramento pike, the hardhead and the black bass. Of the mechanical agencies, they list the following as the more important: irrigation ditches, power dams, stream pollution, and the "inefficiency" of artificial propagation.

A careful observer will be forced to conclude from reviewing the available evidence on causes of depletion of the trout that, while all of the above noted agencies do to a greater or lesser extent affect the number of trout, the angler tends to overlook one important cause, namely, himself. For there is no doubt that depletion upon a large scale began with the advent of the angler.

Age and Growth of Rainbow Trout

As is the case with many other fish, the anatomical structure of the scales of trout furnishes the best means of determining the age of the individuals, and, at the same time, it offers clues to the solution of questions relating to other factors in their life-history.

The scale of the rainbow trout is an epidermal structure which is deeply pocketed anteriorly in a fold of the skin. It first appears on the surface of the body of the very young fish as a somewhat circular plate with thickened edges, which, interrupting the light, makes it look through the microscope like a more or less complete ring. As the fish increases in length, succeeding plates, which appear

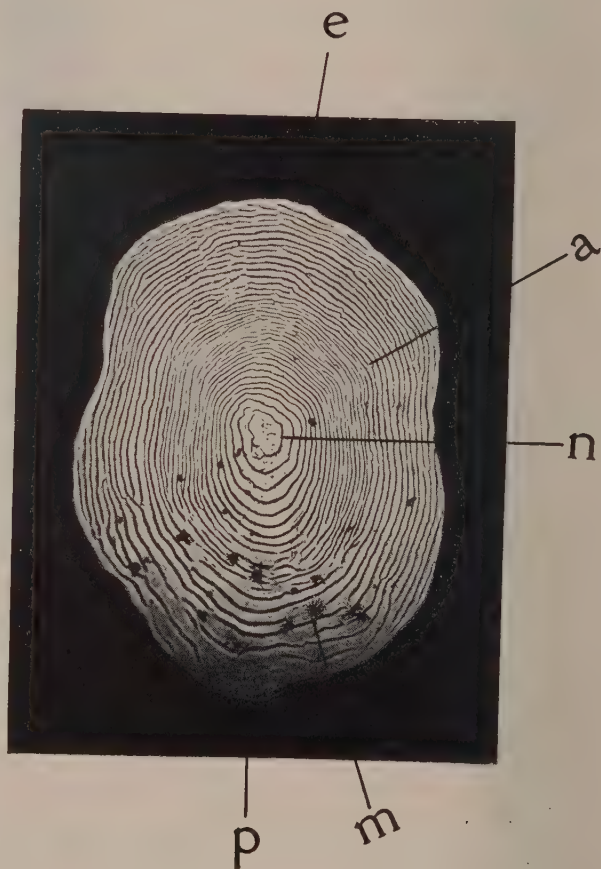


FIG. 118. Trout scale, from fish in its second year, 185 mm., July 7; *e* is anterior end; *p*, posterior end; *n*, nucleus; *a*, annulus; and *m*, melanophore.

as additional rings, usually termed circuli, are added with the growth of the scale. Barring accidents, the scales are never shed, and the growth of the scale bears a rather definite relation to the growth of the body, as is true in other fishes.

A photomicrograph of a scale magnified 34 diameters is presented in figure 118. It is seen to be irregularly oval in shape, with a differentiated anterior part *e*, and a posterior part *p*. The anterior part is the portion which was embedded in the skin, while the posterior end is the exposed part. The central portion *n*, sometimes termed the nucleus, represents the primitive plate, while the surrounding dark rings represent the edges of plates formed through added growth. It will be noted that the rings or circuli are more numerous and regular on the anterior part of the scale. They succeed each other in fairly regular fashion until a region, *a*, is reached where they become somewhat broken and very closely apposed. This narrow region is termed the annulus, and it is known to mark a period of slow or interrupted growth. Beyond the annulus the circuli are farther apart and somewhat more definitely outlined. The fish was taken July 7, when it measured 185 mm. in length.³ The egg from which it was hatched was deposited in late winter or early spring, and as will be seen the primitive plate appeared in the early summer, when the fish measured about 35 mm., while the annulus was formed at some time during the following winter. It may be concluded then that the fish was killed early in the second year of its life.

A scale of a larger fish, 212 mm. in length, is shown in figure 119 *m*, which is also enlarged 34 diameters, as are all other scale magnifications in this paper. It was taken March 11. Three successive annuli are developed: *a'*, *a''* and *a'''*, indicating that the fish was just entering its fourth year of growth. This trout was a little steelhead and the region of the scale exterior to the center annulus *a'''*, is known to represent ocean growth—the broad or widely spaced circuli being characteristic.

In passing it may be noted that the dark spots (see Fig. 118, point *m*) on the posterior part of the scale are melanophores, which, when very abundant, form the black spots of the skin.

The two specimens here figured have unusually regular and well defined circuli and annuli as will be seen when they have been compared with others.

Figure 119 *n* is of a scale from a fish measuring 188 mm. in length and killed August 2. It was in its third year—two annuli appearing, *a'* and *a''*. The widely spaced rings immediately bordering the first annulus, *a'*, indicate a period of very rapid growth.

In order to determine if possible at about what time and at what length of fish the scales first appear, Mr. Hoover made a collection of small fish during the summer of 1927 on ten dates from May 21 to July 21, inclusive, at stations from 3000 to 4300. (See Fig. 117.)

An examination of these fish shows that scales first appear on the sides of the body in the region of the lateral line. For example, a specimen measuring 45 mm. in length and caught on June 4, had scales with two circuli only. These were found in four or five rows above

³ All lengths are standard total length as measured from the tip of the snout to the tip of the middle caudal rays.

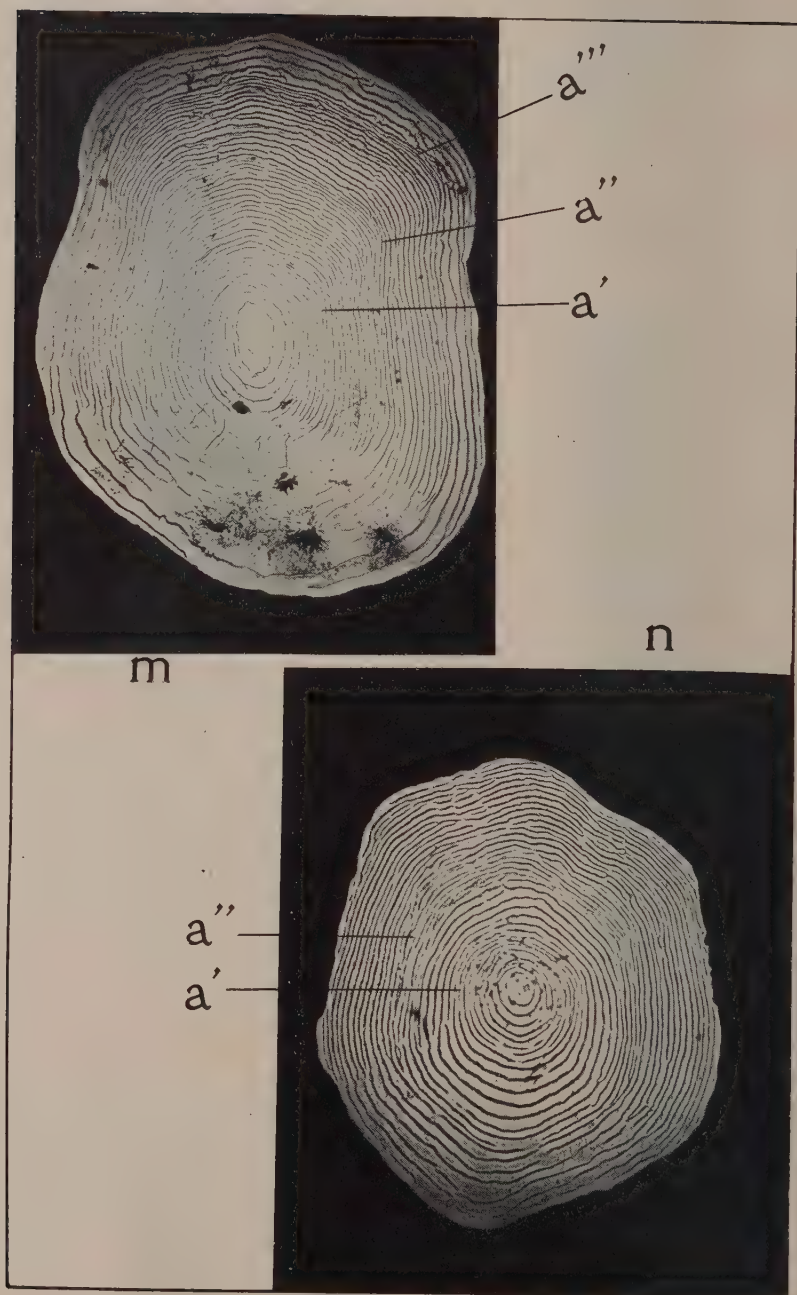
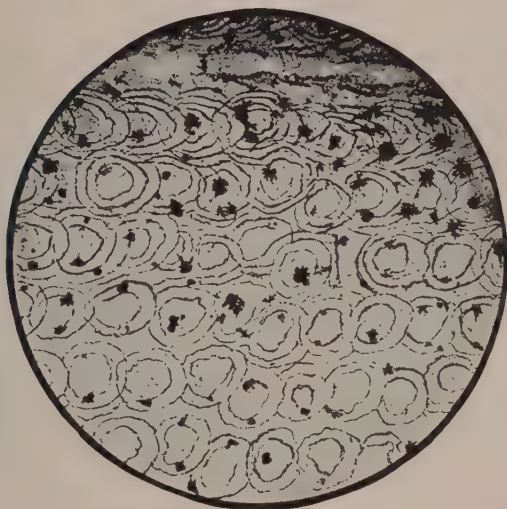
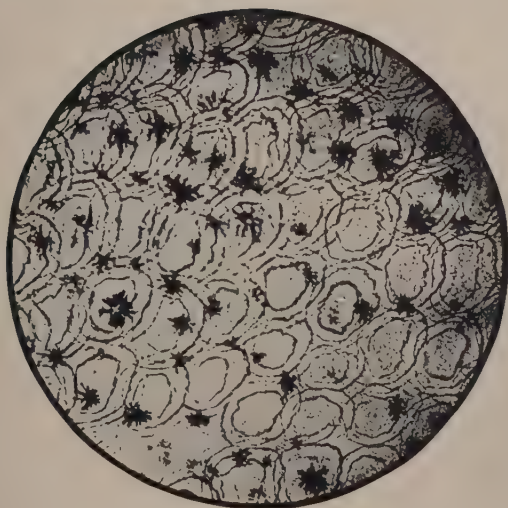


FIG. 119. Trout scales; *m*: 212 mm., March 11; *n*: 188 mm., August 2.



a



b

FIG. 120. Sections of skin with scales adhering, from young trout; a: 52 mm., May 28; b: 48 mm., June 26.

and below the lateral line along the middle of the body. In the region immediately behind the shoulder an occasional single plate appeared, while on the posterior part of the body in the region of the unpaired

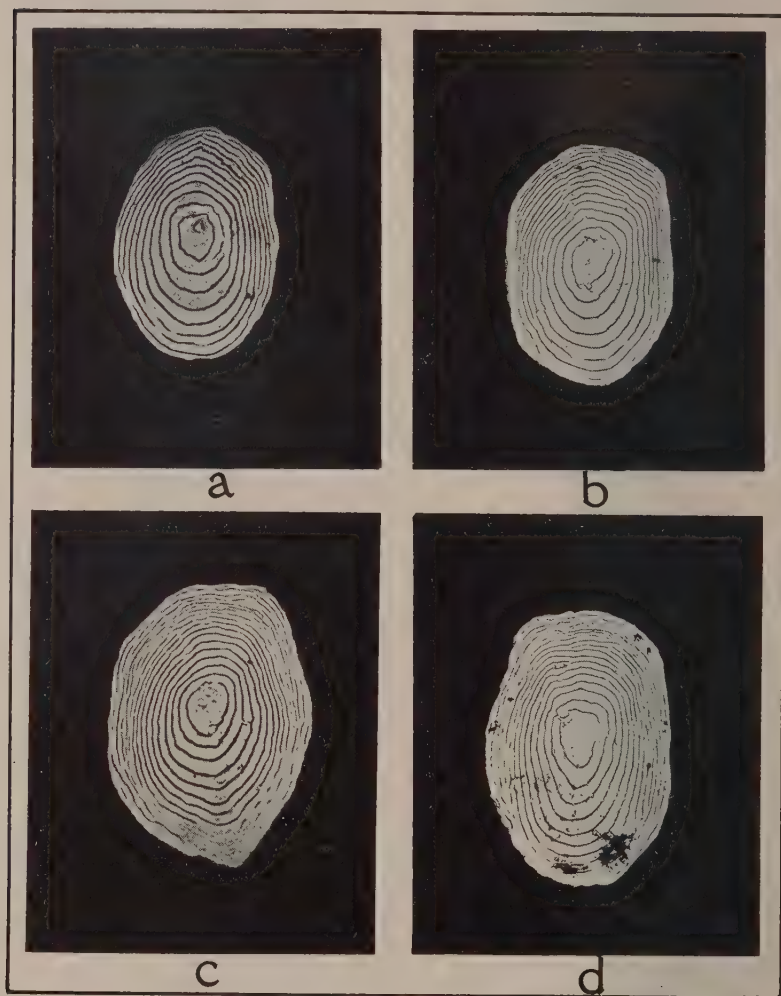


FIG. 121. Scales from young rainbow trout:

- a: 87 mm., July 7
- b: 97 mm., August 15
- c: 107 mm., January 21
- d: 115 mm., February 5

fins, the rows were reduced to two series on the lower side of the lateral line, finally disappearing near the base of the caudal fin. A specimen measuring 52 mm. in length was taken on May 28, and had scales rather well developed over most of the body. Along the lateral line,

both above and below it, and extending from head to tail, were rows of overlapping scales. The largest of these, which in all cases were along the lateral line, had four circuli, and farther down the sides of the body there were not more than two, and occasionally somewhat nearer the ventral surface one circulus, or the outline of the primitive plate only, appeared. This specimen is illustrated in figure 120*a*, where the lateral line with its bordering rows of overlapping scales is definitely shown at the upper side of the figure. The perfect alignment of the scales has been disturbed in freeing the patch of skin from alcohol-hardened mucus.

The next illustration, figure 120*b*, is that of the scales of a fish measuring 48 mm. in length and taken June 26. The body was fairly well covered with scales, some of which had as many as five circuli. Both of these examples (magnified also 34 diameters) seem to have slightly larger primitive plates than is ordinarily the case.

From the examination of this series of young trout, it was found that the scales first appear in the region of the lateral line late in May when the fish is from 35 to 40 mm. in length. Individual variation in the size of the fish of the year is at this time quite pronounced.

Data relating to these fish are assembled in table 1.

TABLE 1

Date (1927)	Length in mm.	Length (mm.) having scales	Number of circuli	Locality station
May 21.....	25-40			3,500
May 28.....	22-52	43-52	2-4	3,000
June 4.....	26-45	41-45	2-3	10,500
June 11.....	29-42	36-42	1-2	4,200
June 19.....	26-45	37-45	1-4	4,300
June 26.....	25-46	36-46	1-5	4,000
	30-62	44-62	4-9	3,000
June 29.....	28-72	35-72	2-13	
July 14.....	30-39	39-	-3	11,000
	33-76	33-76	3-13	9,000
July 18.....	42-64	42-64	5-12	14,500
July 21.....	30-78	32-78	2-12	2,500

As one might expect, trout grow more rapidly during the summer, when conditions such as temperature and food supply are most favorable. Scales of these rapidly growing fish are illustrated in figures 121*a* and 121*b*. In an occasional individual, there appears to be a slowing down of growth early in the fall (*e.g.*, September 9) while others taken in the same vicinity are still growing rapidly. Fish with retarded growth at this time are so much in the minority as not to deserve consideration. Generally speaking, growth continues until early winter, January being the month in which it slows down to a marked degree.

Scales taken from fish, in which very little growth was apparent at the time of capture, are illustrated in figures 122*a* and 122*b*. The first was taken January 14 and measured 139 mm. in length. It is of a fish in the second year of growth and it may be noted that the circuli near the margin of the scales are very closely apposed. Figure 122*b* is of a fish taken February 5, which measured 114 mm. in length. It is in its first year of growth; here again the outer circuli are closely

apposed, forming an annulus. In figures 122*c* and 122*d*, from fish taken February 11 and March 10, respectively, new growth appears beyond the annulus in each case. Figure 122*c* represents a fish which is



FIG. 122. Trout scales:

- a*: 139 mm., January 14
- b*: 114 mm., February 5
- c*: 139 mm., February 11
- d*: 138 mm., March 10

entering its third year of growth, while figure 122*d* is one entering its second year. Returning to figure 121, *c* and *d* represent scales of fish in which new growth has also started. The first of these was from a

fish taken January 21; the second, February 5. Sometimes new growth may have started in December. A scale from a fish taken December 27 showing new growth is illustrated in figure 123*a*. Figures 123*b* and *c* represent fish where new growth has just started or has slightly progressed.

From these and other examples it may be seen that the seasonal retardation of growth does not occur in all fish in the stream at the same time. It seems that most individuals change from slow to rapid growth late in January and in February. Usually, rapid growth has been resumed in March and April and is in full progress in April and early May.

It will be seen that in age determination, account is taken of the presence or absence of the annulus. In figure 121*a* no annulus has formed as yet. The fish from which this scale was taken measured 87 mm. in length and the date of its capture was July 7. From what has been shown relating to the early appearance and growth of the scale, it is safe to conclude that this is a fish of the year in a stage of rapid growth. In figure 122*b*, a fish taken February 5, and measuring 114 mm. in length is represented. Here it will be noted that the circuli are very similar in character as viewed from the primitive plate outward until just before the margin of the scale is reached where a well-formed and very distinct annulus, which represents a check in growth, has appeared. A little later and after growth has been resumed, this fish would be said to have entered its second year growth. It may, even now, and without this new growth, be considered for statistical purposes in its second year. Returning to figure 122*b* for comparison, it will be seen that the scale illustrated in figure 122*b* corresponds to that portion of the scale from the nuclear plate *n* up to and including the annulus *a*. The region beyond the annulus is usually spoken of as the area of second year growth, although the fish was not actually one year old at the time the annulus was formed.

Since in a population of fish the appearance of the annulus is spread over a considerable period of time, it is evident that for practical purposes and to avoid confusion it is convenient to record age as of the calendar year of life.

It may here be remarked that the illustrations are of particularly well-formed and clear-cut scales. Many examples have irregularities of various kinds which at times render age determination difficult or doubtful. When material is collected for study, the samples should contain large numbers of scales so that provision may be made for faulty ones.

Following the above brief description of the method of age determination, a tabulated analysis of the ages of some 795 fish at the time of capture is here given. (See Table 2.) The table does not include fish of the fourth year-class, eight in number, collected in January, February and March. Including these, the totals and percentages would be as follows:

First year: males 16, females 13, 3.65 per cent

Second year: males 312, females 275, 73.84 per cent

Third year: males 92, females 79, 21.51 per cent

Fourth year: 8 fish, 1.00 per cent

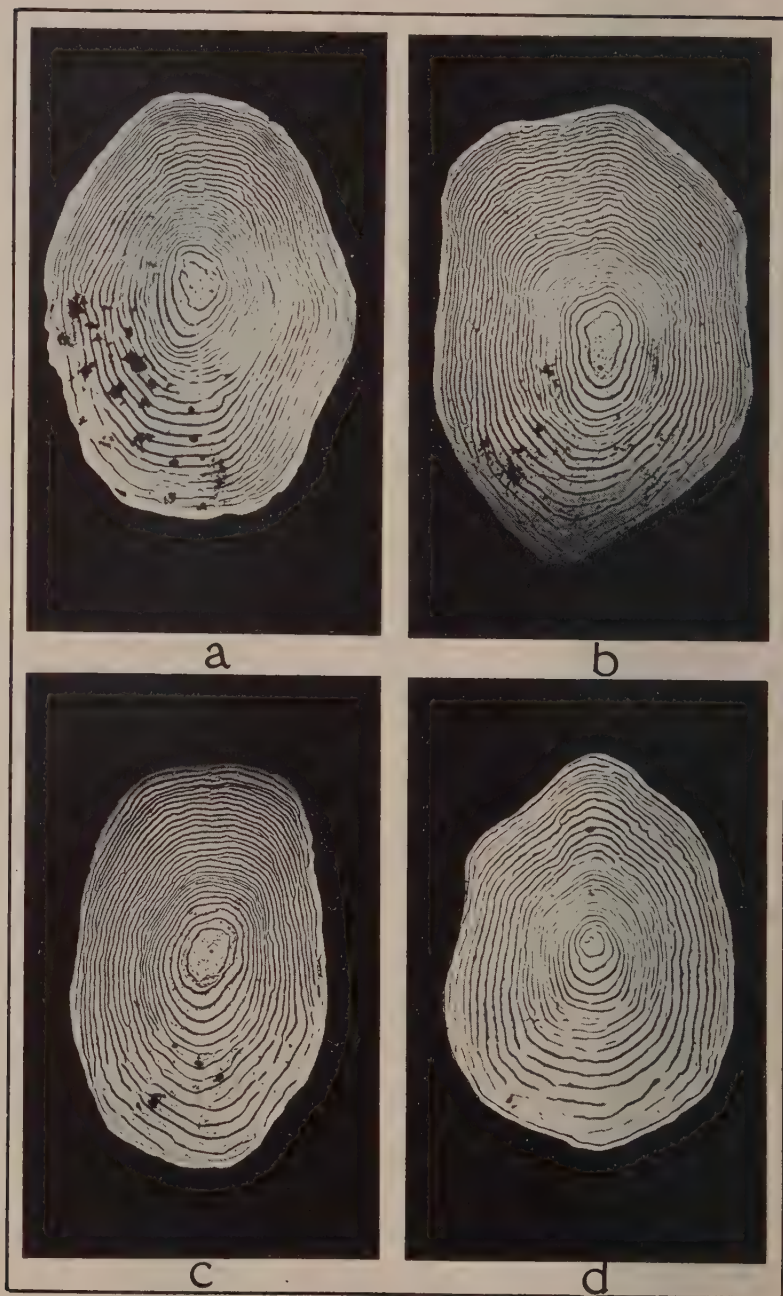


FIG. 123. Trout scales:

a: December 27

b: February 11

c: February 26

d: March 4

It appears that second year fish furnish the mass of the catch. They number some 73.8 per cent, while third year fish are represented by about 21.5 per cent. Average lengths of these year-classes as they appear in the catches by the month are given in tables 2 and 3.

TABLE 2
Age Groups in the Angler's Catch

Date 1927-1928	Maximum and minimum lengths in mm.	First year		Second year		Third year	
		Males	Females	Males	Females	Males	Females
May 1.....	97-170			6	8	2	4
May 8.....	114-167			9	8		
May 15.....	95-152			11	8	2	
May 21.....	124-173			11	12	1	
May 28.....	106-160			19	7		1
Totals.....				56	43	5	5
Per cent.....				90.82		9.18	
June 4.....	80-166	1		7	9	1	
June 5.....	94-225			12	9	4	2
June 11.....	88-190	1		9	13	1	1
June 18.....	117-193			16	9	1	
June 29.....	124-222			16	9	1	1
Totals.....		2		60	49	8	4
Per cent.....		1.62		88.62		9.76	
July 2.....	115-194			12	14	1	1
July 4.....	101-164			9	5		
July 7.....	87-198	1		12	10	1	
July 14.....	107-202			16	8		1
July 18.....	90-161		1	14	5		2
July 21.....	130-202			13	9	4	4
July 28.....	78-196	2	1	10	11		1
Totals.....		3	2	86	62	7	9
Per cent.....		2.94		87.58		9.48	
August 2.....	125-195			10	12		
August 12.....	91-183	1	1	8	9		
August 15.....	97-163		1	3	3		
August 19.....	92-138		1	1	3		
August 28.....	128-212			2	6	1	
Totals.....		1	3	24	33	1	
Per cent.....		6.45		91.94		1.61	
September 9.....	77-211	1	1	10	9	1	1
September 11.....	135-191			4	3		1
September 14.....	125-176			3	5		
September 22.....	133-191	1		7	11		
September 24.....	155-196			3	3		
September 28.....	139-148			3	3		
Totals.....		2	1	30	34	1	2
Per cent.....		4.28		91.43		4.28	
October 9.....	92-184	1		1	2		
October 15.....	91-213	1		6	7	1	
October 23.....	74-179	1	2	4	2		
Totals.....		3	2	11	11	1	
Per cent.....		17.86		78.59		3.57	
November 5.....	99-199		1	2	1		

TABLE 2—Continued
Age Groups in the Angler's Catch

Date 1927-1928	Maximum and minimum lengths in mm.	First year		Second year		Third year	
		Males	Females	Males	Females	Males	Females
December 4	174-256			2	2	3	2
December 10	104-210	2		1	1	1	
December 11	102-254	1	3	7	5	1	
December 17	193-258				2	2	
December 18	122-211			2		1	
December 27	127-191			2	8	1	
December 28	94-184	1		2			
December 31	103-251	1	1	8	10	2	1
Totals		5	4	25	30	11	3
Per cent.		11.45		70.52		17.94	
January 7	96-256			1	3	4	1
January 8	99-252				2	8	5
January 14	86-217			1	2	8	6
January 21	95-241			1	2	3	2
Totals				3		23	14
Per cent.				24.50		75.50	
February 5	114-169			1	1	1	3
February 11	127-301					4	1
February 12	146-232					4	2
February 18	123-201				1	3	1
February 19	110-232			1	1	5	5
February 25	105-185			3		1	1
February 26	110-245				1	2	3
Totals				5	4	20	16
Per cent.				20.00		80.00	
March 3	145-179					1	2
March 4	127-215			1	1	7	7
March 10	127-229			1	1	1	2
March 11	112-212			3		1	2
March 18	113-214				1	1	6
March 31	153-184				1	1	1
Totals				5	4	12	20
Per cent.				21.95		78.05	
April 7	92-262			3	3	1	4
April 21	134-192			2	1	2	2
Totals				5	4	3	6
Per cent.				50.00		50.00	

TABLE 3
Size of Trout in the Angler's Catch, by Age Groups and Months

FIRST YEAR-CLASS

Month when caught	Average length in mm.	Average length to nearest eighth-inch
June.....	84	3 $\frac{1}{4}$
July.....	83	3 $\frac{1}{4}$
August.....	103	3 $\frac{1}{2}$
September.....	110	4 $\frac{1}{8}$
October.....	100	4
November.....	99	3 $\frac{7}{8}$
December.....	101	4

SECOND YEAR-CLASS

Month when caught	Average length in mm.	Average length to nearest eighth-inch
January.....	115	4 $\frac{1}{2}$
February.....	117	4 $\frac{3}{8}$
March.....	138	5 $\frac{3}{8}$
April.....	131	5 $\frac{1}{8}$
May.....	133	5 $\frac{1}{4}$
June.....	142	5 $\frac{5}{8}$
July.....	141	5 $\frac{1}{2}$
August.....	143	5 $\frac{5}{8}$
September.....	156	6 $\frac{1}{8}$
October.....	169	6 $\frac{5}{8}$
November.....	206	8 $\frac{1}{8}$
December.....	170	6 $\frac{1}{4}$

THIRD YEAR-CLASS

Month when caught	Average length in mm.	Average length to nearest eighth-inch
January.....	173	6 $\frac{3}{4}$
February.....	167	6 $\frac{5}{8}$
March.....	168	6 $\frac{5}{8}$
April.....	178	7
May.....	141	5 $\frac{1}{2}$
June.....	175	6 $\frac{7}{8}$
July.....	165	6 $\frac{3}{4}$
August.....	212	8 $\frac{3}{8}$
September.....	171	6 $\frac{3}{4}$
October.....	213	8 $\frac{1}{2}$
November.....	---	---
December.....	229	9

When compared with the adult steelheads, these little fish are rather insignificant. Where fishing is intensive, smaller fish are taken in larger numbers, and it is altogether likely that a similar study of anglers' catches in certain other streams would reveal a much larger proportion of the younger fish.

At the present time the legal open season extends from May 1 to the end of October with no size limit. During this time the fish of the year have attained size enough to be caught with ease, and therefore practically no protection is offered the young of the species.

Sex Representation in the Catch

In an attempt to augment the supply of trout available to fishermen in depleted streams, it is the practice to resort to artificial propagation. To supply the eggs for such propagation it is the custom in

many places to spawn wild fish collected from their native waters. To gather the eggs it is necessary to place traps across the streams to intercept migrating adult fish on the way to their spawning grounds. The traps are placed in the streams before migration begins and are left there as long as is desired. Frequently they remain until fish no longer approach them. Such traps form effective barriers and are usually constructed in such a way as to lead the fish which enter them into holding tanks from which the males and females are segregated and eventually spawned. Hatchery men attending these traps have reported that this procedure reveals a shortage of male fish and that in some cases this shortage becomes acute. Much speculation has been

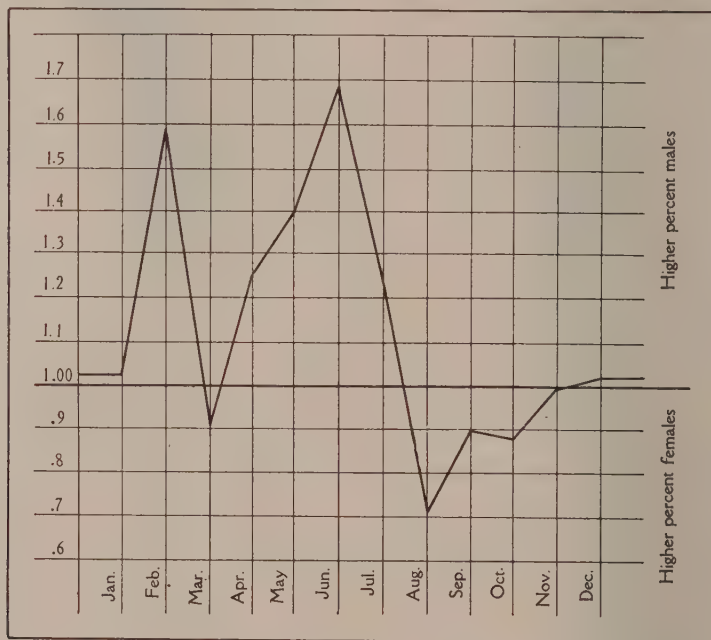


FIG. 124. Seasonal variation in the ratio of males to females, Waddell Creek rainbow trout.

indulged in as to the cause of this shortage. Some claim that the females precede the males in the migration by a considerable length of time, and that the males are more shy than are the females and refuse to approach the traps, remaining downstream and away from them. Others insist that the anglers are responsible for the lack of male fish, assuming that this sex will strike a baited hook more readily than will the female.

As a possible contribution to the ultimate settlement of the angler's responsibility, table 4 has been prepared, showing by monthly periods the number of male and female fish caught in Waddell Creek throughout the year.

TABLE 4
Sex Representation in the Catch

Month	Number of males	Number of females	Month	Number of males	Number of females
May.....	63	41	November.....	2	2
June.....	72	43	December.....	41	40
July.....	98	78	January.....	37	36
August.....	27	42	February.....	35	22
September.....	36	40	March.....	25	27
October.....	15	17	April.....	15	12

It will be seen that in the above table there are the sex records of 866 fish. Of these, 466 are males whereas 400 are females, making an excess of 66 males in the season's catch (53.8 per cent male; 46.2 per cent female). A seasonal variation in the sex ratio is indicated in table 4, and is represented in figure 124, although the numbers involved are too small to warrant definite conclusions.

Summary

The species of trout which inhabits Waddell Creek is *Salmo irideus* Gibbons.

This species is of wide distribution and subject to certain variations.

Waddell Creek is typical of other Coast Range streams, and in miniature it presents most of the prominent physical and biological features of larger coastal streams such as Eel and Klamath rivers.

The fish fauna of Waddell Creek, like that of other coastal streams which enter the ocean between the Golden Gate and Monterey Bay, has no truly fluvial fish.

The more important fishes of Waddell Creek are members of the family Salmonidae, the silver salmon and the rainbow trout.

The life-history of the rainbow trout has a stream and ocean phase. This report is concerned with an angler's catch of the stream phase.

In recent years the trout of the coastal streams have become greatly depleted because of various adverse conditions, principally the activities of anglers.

Very little of an exact nature relating to the ages of the stream trout taken by anglers is available.

The structure of the scales of trout offers reliable data relating to the age and growth of the fish.

Scales first appear on the body in the month of May, when the fish has attained a length of 35 to 40 mm.

Growth is more rapid in the summer than in the winter. Growth progress is apparent in the structure of the scale, rapid growth forming wider circuli, whereas retarded growth such as occurs at some time during the winter forms a narrow area of closely apposed circuli known as an annulus. In determining the age of a trout the presence or absence of an annulus in a scale is an important factor.

In Waddell Creek the annulus generally forms late in January or early in February.

New growth following the completion of an annulus appears early in the spring. Most of the fish begin rapid growth by the middle of April or early in May.

Year groups are represented in the angler's catch as follows: first year group, 3.65 per cent; second year group, 73.84 per cent; third year group, 21.51 per cent; and fourth year group, 1 per cent.

There appears to be a predominance of males in the catch.

Fish remain in the stream from one to three years before migrating to the ocean.

The anglers' catch heavily depletes the younger fish and it appears to the writer that the present legal open season offers very little protection.

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Much of the literature that concerns itself with rainbow trout is devoted to description and distribution or to the sporting qualities of the fish. The former is to be found mostly in technical papers, whereas the latter is spread throughout the popular papers and magazines. Relatively little of an exact nature, however, has been written concerning life-histories, habits and growth. The following references have proved useful:

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SECOND REPORT OF SARDINE TAGGING IN CALIFORNIA ¹

By JOHN F. JANSSEN, JR.

California State Fisheries Laboratory

Division of Fish and Game

Introduction

A thorough knowledge of the migrations of a fish population which is exploited as intensively as that of the California sardine, *Sardinops caerulea* (Girard), is essential to a practical administration of the fishery. One method of tracing migrations is to tag or mark fish in such a way that individuals may be recognized if caught again. Releasing large numbers of tagged fish with subsequent recovery of the tags will yield valuable information, not only concerning the routes and extent of travels, but will demonstrate whether different regions harbor distinct populations or whether the entire population of all regions is homogeneous. It will show as well whether different portions of the population have different habits of migration, and whether a heavily fished region will be replenished by fish from other localities. Furthermore, if tag recoveries are extensive enough, we can approximate the size of the population and the intensity of fishing—the proportion of the entire population removed each year by fishing operations. When a species is fished over a large area this information is of additional value in determining the relative fishing intensity in each region. This is the case with the California sardine. It is caught for canning and reduction purposes or for bait from British Columbia (Canada) along the entire Pacific Coast of the United States to the southern tip of Lower California (Mexico).

Although a definite migration theory had been formulated from various phases of the sardine investigation carried out by the State Fisheries Laboratory of the California Division of Fish and Game, a tagging program was inaugurated to check it. Results from two years of tagging have been entirely in accord with that theory: nearly all spawning takes place off southern and Lower California; the young fish remain in these southern waters until adolescent, when they begin northerly migrations, going at first as far as central California and returning the following spring to southern California to spawn; as the fish grow older they go farther and farther north at the close of each spawning season, so that by the time they are eight or ten years old they make annual migrations as far as British Columbia but return to southern waters to spawn.

A preliminary report on sardine tagging in California was made in 1937 (Janssen, 1937). In it were presented the methods of tagging and tag recovery as well as an enumeration of recoveries from fish tagged up to that time. Since the writing of that report, the California

¹ Submitted for publication, August 10, 1938.

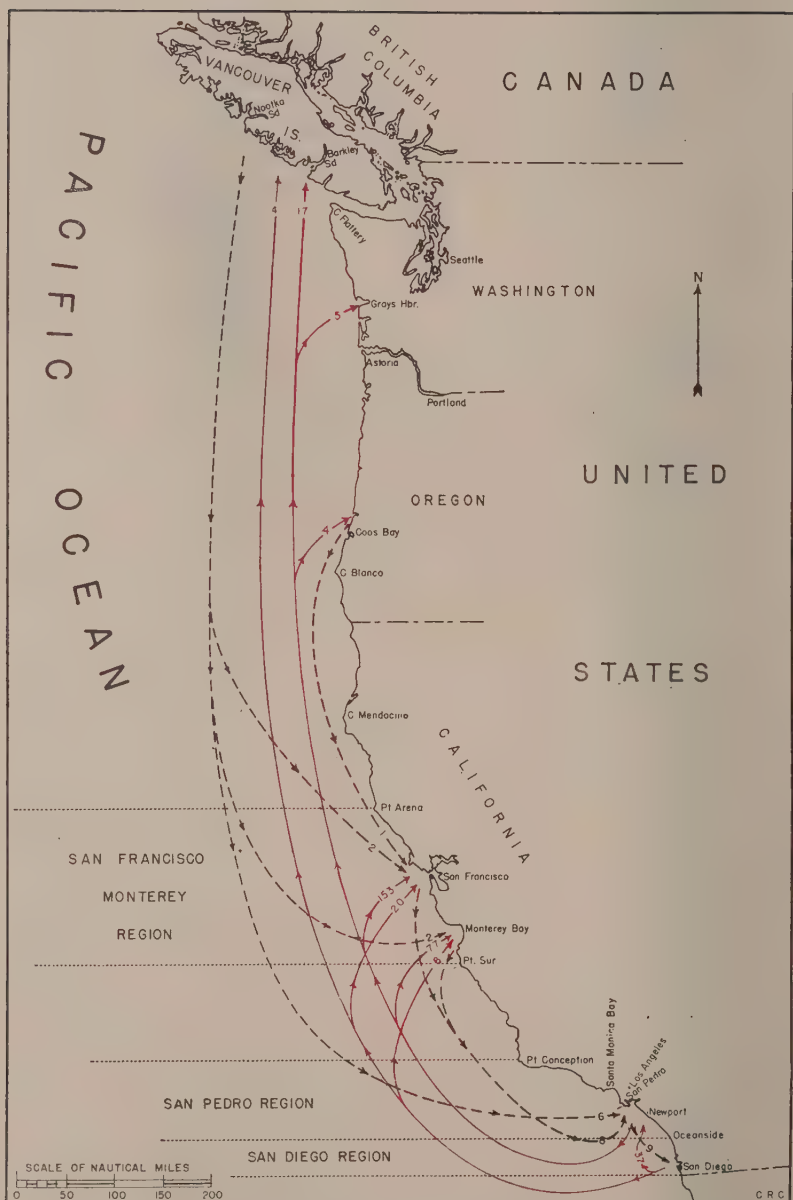


FIG. 125. A section of the Pacific Coast showing diagrammatically major movements of tagged sardines from one fishing region to another, as indicated by recoveries during the period March, 1926-June, 1938.

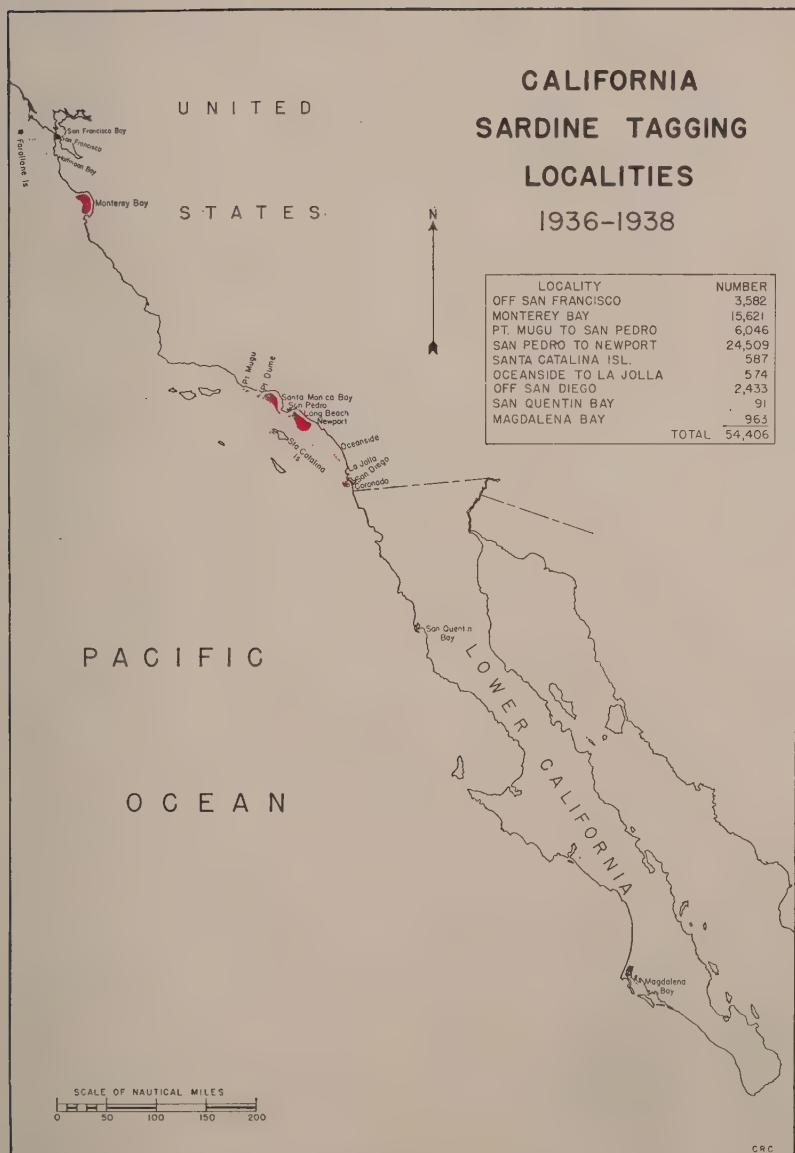


FIG. 126. A section of the Pacific Coast showing the localities where the California Division of Fish and Game has tagged sardines. The number of dots indicates the concentration and range of tagging in each area.

Division of Fish and Game has tagged an additional 28,238 sardines in California waters and 963 along the coast of Mexico. Tags from a great many of these fish have already been recovered as well as additional tags from groups of fish discussed in the previous report. Five more British Columbia tags (Hart, 1938.2) have been recovered in California reduction plants, making a total of ten for two seasons. One Oregon tag has also been taken in our State. Thirty California tags have been recovered in regions north of California (Janssen, 1938) as follows: 21 in British Columbia, 5 in Washington and 4 in Oregon. Of the California tags recovered in British Columbia, one was out only 103 days; the longest period was 208 days; and the average was 169 days. These fish traveled a minimum of about a thousand nautical miles or an average of about 6 miles per day.

There was a decided movement of tagged sardines from southern California into central California waters. (See Table 1 and Fig. 125.) Also many of these fish continued north to the coast of Washington where the major part of the 1937 British Columbia catch was made. A southern movement of tagged sardines is also evident. Too few fish have been tagged in Mexican waters to yield any returns. Until recently there has been no means of recovering tags in Mexico so that it has been impossible to trace movements of sardines south of San Diego.

TABLE 1
Summary of Sardine Tag Recoveries, March, 1936 June, 1938

Tagging region	Total number tagged by regions, March, 1936 to June, 1938	Per centage of total tagged	Number of recoveries by regions							Total number recovered
			Recovered in British Columbia	Recovered in Washington	Recovered in Oregon	Recovered at San Francisco	Recovered at Monterey	Recovered at San Pedro	Recovered at San Diego	
San Francisco-Monterey.....	19,203	35.30				226	138	8		372
San Pedro.....	31,142	57.24	17	5	4	153	77	605	9	870
San Diego.....	3,007	5.53	4			20	8	37	5	74
Lower California.....	1,054	1.94								
Broken Tags.....						1	2	15		18
Totals.....	54,406	100.00	21	5	4	400	225	665	14	1,334
British Columbia.....	10,449		63	9	9	2	2	6		91
Oregon.....	2606				2	1				23

¹ Fish tagged by British Columbia authorities (Hart, 1938.2). Many of these fish were tagged off the coast of Washington.

² Fish tagged by Oregon authorities. Published by permission of the Fish Commission of Oregon.

TABLE 2
Extent of Migration of Tagged Sardines

Distance traveled in nautical miles	Number of fish moving	
	North	South
50 or more.....	325	28
330 or more.....	288	19
360 or more.....	58	11
640 or more.....	30	10
940 or more.....	26	6
1000.....	4	0

The "Small" Tag

The tag used for sardine marking (Janssen, 1937) is of the internal type closely resembling one in use by the U. S. Bureau of Fisheries in its Alaskan herring investigation (Rounsefell and Dahlgren, 1933). It is a flat strip of nickel-plated steel and is recovered by means of electro-magnets placed in the meal lines of reduction plants (Fry, 1937).

A tag identical to but somewhat smaller than the one described in the 1937 report has been tried. It is intended primarily for use in fish considered too small to be tagged with the larger type. The small tag has, however, been used in some large fish as well as in many of the fish for which it was designed, sardines ranging from 135 to 200 mm. total length (115 to 170 mm. body length).

The dimensions of the small tag are $\frac{1}{2}$ inch by $\frac{1}{8}$ inch by $\frac{1}{40}$ inch. On one side there is a serial number preceded by a letter and on the opposite side the inscription "C. F. & G."

Because of the small size of these tags it was expected that the electro-magnets used for tag recovery would not pick them up as efficiently as the large tags. Experiments performed in reduction plants with small numbers of tags have borne this out but the difference is too small to be significant. Repeated experiments with large numbers of tags, however, are planned for the future.

Sizes of Sardines Tagged

In discussing sizes of sardines tagged, it is convenient to divide them arbitrarily into three general groups—large, medium and small. We regard as small fish those under 200 mm. total length (170 mm. body length). Medium fish range from 200 to 270 mm. and large fish are those over 270 mm. total length (229 mm. body length).

Since obtaining the small tags in October, 1937, as many small sardines as possible have been tagged. The large tags have seldom been used in fish under 180 mm. total length (153 mm. body length). When using the small tags, all fish above 150 mm. total length (127 mm. body length) have been tagged and a few as small as 135 mm. (115 mm. body length).

Preliminary experiments on tagged fish held in a tank indicate that 135-mm. sardines, and possibly smaller, may be tagged without excessive mortality. However, the smaller sizes lose their scales more easily than larger sardines and consequently suffer considerably more from handling. Further experiments are necessary to definitely determine the size of the smallest fish which may be tagged.

The majority of the sardines tagged during the past year fall into the medium class. Considerably fewer large fish were tagged than during the previous year.

Tag Loss

Tag loss may be considered as the loss of tags by any means whereby they can not later be recovered. Tags may be lost in a variety of ways such as death of the fish due to injury at time of tagging, shedding of tags by the fish, inefficiency of the magnets used to recover the tags, loss of tags in the canning and reduction plants

and in many other ways. All of the various sources of error must be considered when attempting to analyze tag recoveries.

It is difficult to determine accurately the mortality due to the effect of the tag as well as that due to handling and confinement of the fish while tagging is in progress. The death rate, as a result of tagging, probably differs between small and large fish. Mortality experiments in a holding tank, which are now under way, should throw more light on this subject. Calmness of the ocean while tagging is being performed is a very important factor, as in rough weather sardines become battered both in the net in which they are caught and in the live box or net from which they are tagged. On a calm sea the fish can usually be released in first class condition. Again, if the sardines are concentrated too tightly in the net or if sea lions get into the net creating a panic, the fish quickly lose their scales and weaken.

Preliminary results from experiments where tagged sardines have been held for over two months in a tank show that some tags are shed, although the proportion is not as yet known. This loss is probably greater among small fish than larger ones, but a final answer must await results of the holding experiments.

Another source of tag mortality which must be quite considerable is from predators. Especially is this true while the fish are still weak from the operation and before they have found a school where they are more or less protected. Frequently the presence of predatory fish is known. In several instances sardines were tagged in the immediate vicinity of pleasure fishermen catching bonito and large mackerel. Live sardines of similar size as those being tagged were used for bait. After the ordeal of acquiring a tag it must have been difficult for a sick sardine to evade such fast swimmers as fish of the mackerel tribe. Unfortunately, in these cases, it was impossible to tag the fish elsewhere, yet a surprising number of these tags were later recovered. Predatory fish must frequently be lurking below without our knowledge. On February 8, 1938, a load of sardines was being tagged from the live box in Newport Harbor. A member of the boat crew caught six rock bass (*Paralabrax nebulifer*) on hook and line, using live sardines as bait. The stomach and intestinal contents of each fish were examined, and in one was found a sardine which had been tagged and released at the same place the day before.

Sea gulls are often a serious menace during the day and especially when fish are being tagged under way. Some of the tagged fish stay near the surface long enough to be picked up by a watchful gull. To verify these observations one gull was shot, and tagged sardines were found in its crop. Cormorants and several other species of diving birds have been observed catching tagged fish when first released. Porpoise and more often sea lions are frequently such a serious menace while fish are being tagged that drastic measures are sometimes necessary to discourage them.

In addition to the fact that not all sardine reduction plants have magnets, the fresh fish market catch unquestionably accounts for the loss of many tags as there are no recovery devices at the markets. To this must be added the loss of tagged fish in the enormous live bait

fishery in southern and Lower California waters, not to mention the dead bait fishery farther north.

Every sardine cannery operates a reduction plant to reduce canning offal as well as whole fish. During conveyance of cannery offal to the reduction plant a large proportion of the tags are lost. Consequently for each ton of fish received, plants running straight reduction may be expected to pick up more tags than combined canning and reduction plants.

On the other hand, there is a considerable tag loss even in reduction plants where magnets are installed. No two magnets are equally effective and the efficiency of any one may vary from week to week. Furthermore, the effectiveness of the recovery system depends upon the interest the reduction plant employees take in the experiment. If magnets are cleared of their scrap carefully and frequently a good many more tags are recovered per unit quantity of meal than in plants where no one cares about clearing the magnet. The installation of a magnet, such as its angle of inclination, proximity to other metal, rapidity of meal flow and several other considerations, all affect the number of tags recovered. Several experiments have been performed which demonstrate fluctuations in magnet efficiency. More extensive experiments are planned for the 1938-39 sardine season. They should yield a reasonably reliable measure of the efficiency of each magnet and its changes throughout the season. These data are fundamental if a measure of fishing intensity is to be obtained from tag recoveries.

Mechanical Tabulation of Tag Recoveries

An analysis of tag returns obviously necessitates the tabulation of recoveries in a number of different ways. As returns become more numerous (over 1300 at the present writing) the task of organizing the data becomes increasingly involved. This task has been much simplified by the use of the Division of Fish and Game Hollerith

Species	Type of Tag	Year	Load Number	Block area of release	Tag number	Length when released	Date of recovery	Region of recovery	Plant in which recovered	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
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9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9

FIG. 127. Facsimile of punched card used in tabulating sardine tag recoveries.

electrical statistical equipment (Conner, 1935) to record tag recoveries on punch cards. Each card has 45 vertical columns of consecutive numbers from 0 to 9. (See Fig. 127.) All pertinent information relating to each recovered tag is coded into numbers. The system is quite flexible so the method may be applied to any species of fish which

may be tagged. Space is provided on each card for coding additional information which may be found useful in the future, but has not seemed important at the present time. An electric key punch is used to transfer the code to the card by punching out the code numbers.

A sorting machine arranges the cards in any desired order or separates any group or individual card from the rest. A mechanical tabulator automatically combines and summarizes any desired information appearing on the sorted cards and presents the data in printed form.

Fishing Seasons

Although sardines are tagged to some extent the year around, recoveries can only be expected during the canning and reduction season as tags are recovered by electro-magnets in the reduction plants. During the remainder of the year considerable quantities of sardines are caught for bait but tags in any of these fish are lost. In British Columbia, Washington and Oregon the canning and reduction season starts in June or July and continues as far into October as weather and availability of fish permit. In the San Francisco-Monterey region the season lasts from August 1 to February 15 of the following year. In the San Pedro and San Diego regions the canning and reduction season starts on November 1 and ends the following March 31.

Tagging and Recovery by Regions, June, 1937—June, 1938

San Francisco-Monterey region

During the first season of tagging in the San Francisco-Monterey region a live car was used to hold the sardines to be tagged (Janssen, 1937). Returns from these fish were exceedingly few compared with recoveries from sardines held for tagging by other means. As returns from fish tagged from a live box on the deck of a fast 45-foot cruiser off southern California were highly satisfactory, this method was tried off central California in the fall of 1937. The returns were equally numerous from the fish released during September, October and November in the vicinity of the Farallone Islands and in Monterey Bay. (See Table 4.)

The sardine fishing grounds off San Francisco extend a considerable distance offshore so that tagging in this area was practically all done while cruising on the open ocean rather than carrying the fish to a sheltered cove where the operation could be performed more comfortably. The fish were released one at a time as tagged and consequently spread over a wide area. Sea lions and cormorants are so abundant in the vicinity of the Farallones that it was never practical to lay in their lee when fish were obtained in that vicinity. In Monterey Bay fish were frequently tagged in harbors, but occasionally while cruising at sea.

As shown in table 1, there have been 372 recoveries from the 19,203 sardines tagged in the San Francisco-Monterey region. Of these 350 were from the 10,981 fish tagged during the past year. Although 258 tags have been recovered in central California from fish released in southern California, only eight central California tags have been recovered in the south. This is a satisfactory recovery in view of the fact that relatively few fish were tagged in central Cali-

fornia waters compared with the number tagged in the south. In addition the sardines released between San Francisco and Monterey were tagged early in the season and consequently were subjected to an intensive fishery over a period of several months. The tagged fish stock left to move south was therefore quite small.

Disregarding the floating reduction fleet which operated off San Francisco beyond the three-mile limit, there were 22 plants operating on or near San Francisco Bay during the 1937-38 sardine season (Dado, 1938). Of these plants, 12 were equipped with magnets, an increase of 5 magnets over the previous season. Practically all meal from the floating reduction fleet was ground in one plant at San Francisco which is also equipped with a magnet. During the past sardine season the magnets in the San Francisco area accounted for 372 California tags and one Oregon tag.

On Monterey Bay there were 12 plants operating during the 1937-38 season. Of these, 10 were equipped with magnets, an increase of 3 magnets over the previous season. These magnets picked up 193 California tags and 2 British Columbia tags during the past season.

San Pedro region

The 31,142 sardines tagged in the San Pedro region have yielded 870 returns. Of these, 360 were from the 16,427 sardines tagged since June, 1937. A good many of these fish were released since the close of the canning and reduction season so there will be no opportunity for recoveries until the 1938-39 season commences.

Sardines released in the San Pedro region have been recovered in all the major sardine fishing localities on the Pacific Coast. The plants on Vancouver Island, British Columbia, have accounted for 17 tags from this region; Washington, 5; Oregon, 4; San Francisco, 153; Monterey, 77; and San Diego, 9. (See Tables 1 and 4.) Recoveries in central California were more numerous from sardines tagged in southern California late in the 1936-37 season than from those released early the same season. Since the large sizes presumably make the longest migrations this may be partially due to the fact that a greater proportion of large fish were tagged late in the season. But probably more important is the fact that the fish tagged early in the season were subjected to a longer fishery. Therefore the tagged stock was reduced considerably before the northerly migration started.

Methods of obtaining and holding fish for tagging in the San Pedro region were the same as during the previous year. It has been the policy, however, when using the live box to tag and release the fish while cruising at sea whenever possible rather than release the fish at one place or in harbors. The chief advantage of this system is to get the fish back into the ocean quickly and consequently in good condition. Transporting them to a snug anchorage where tagging can be done more conveniently is frequently time-consuming. Returns are usually better from fish held but a short time. Although tagging is slow when the sea is rough, releasing the fish sooner and consequently in better condition, compensates for any disadvantages or inconveniences. On occasion it is possible to lay to and tag on the open ocean but the boat is usually steadier when cruising into or away from the seas.

One more magnet was in operation in the San Pedro region during the 1937-38 season than during the previous season, making a total of 10 magnets for 14 plants. These magnets have accounted for 431 California tags and 3 additional British Columbia tags during the past year.

San Diego region

As during the 1936-37 season, three of the four plants were provided with magnets. These magnets recovered only one sardine tag during the past year. This is explained by the fact that very few sardines were handled in these canneries and reduction plants.

Four of the tags released in the San Diego region in the spring of 1937 were recovered in British Columbia the following summer; and during the 1937-38 season in California, 20 of these tags appeared at San Francisco, 8 at Monterey and 4 at San Pedro.

Since the spring of 1937 only 830 sardines have been tagged in the San Diego region. These were all very small fish and were in comparatively poor condition. The intensive bait fishery in this region will undoubtedly account for a good many survivors making the chance of any recoveries very small.

Lower California

No means were provided until recently for the recovery of sardine tags in Mexico. There is a small sardine fishery out of the port of Ensenada and two plants have installed magnets. However, so few fish are reduced that at best few tags may be expected from that source. There is a good sized bait fishery along the coast of Lower California which unquestionably takes many of the small fish tagged in that territory. Unfortunately, no recoveries can be obtained from fish used as bait.

In April, 1938, 963 sardines were tagged in Magdalena Bay, about 580 miles southeast of San Diego. This is the southernmost locality in which sardines have been tagged.

Differential Movements of Medium and Large Sized Sardines

From the sardines tagged off southern California during the late winter and early spring of 1937, there have been recoveries in all the major sardine fishing areas on the Pacific Coast. Since there was a wide range of sizes tagged during this period, data on these fish were analyzed to determine whether the larger tagged fish made longer migrations than the smaller and medium sizes. From the recovery data, four frequency polygons were made of the lengths of the fish recovered in different areas. (See Fig. 128.) Since it is impossible to determine the length of tagged sardines at the time they are recovered, the total lengths of each fish at the time of tagging were used. To obviate the necessity of a correction for growth, only recoveries obtained over a limited period of time were considered. Frequency polygon I includes all fish caught soon after tagging in the same fishing region as tagged. This curve should represent a cross-section of the survivals from the late winter and early spring tagging in southern California in 1937. The next frequency, II,

includes the tagged sardines recovered in British Columbia, Washington and Oregon in the summer of 1937 from this same southern California tagging. Frequency III represents recoveries of these southern tagged

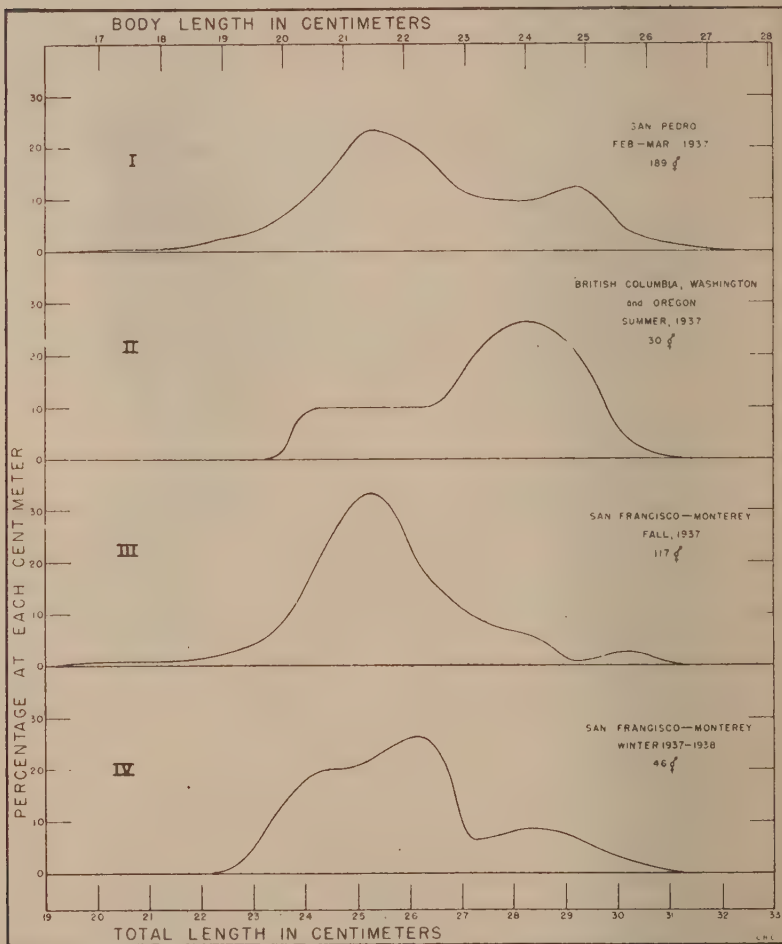


FIG. 128. Length frequency polygons of a group of tagged sardines recovered at different localities along the Pacific Coast. The fish were all tagged and released in southern California waters, January-March, 1937. The lengths given are the sizes at time of tagging, not at time of recovery. Frequency I shows the sizes of fish recovered at San Pedro within a few weeks after tagging; Frequency II, fish recovered in British Columbia, Washington and Oregon in the summer of 1937; Frequency III, recoveries at San Francisco and Monterey in the fall of 1937; and Frequency IV, recoveries at San Francisco and Monterey in the winter of 1937-38.

fish taken in the fall of 1937 at San Francisco and Monterey, and the last curve, IV, includes the recoveries in this same region during the winter of 1937-38.

If all of these fish, irrespective of size, had the same habits of migration, the frequency polygons should obviously be quite similar. Since they are apparently different, a reliability test was applied to aid in the proper interpretation of their differences. χ^2 gives a satisfactory measure of the probability that two frequencies are samples of the same population if each frequency is composed of over 100 individuals. The t test may be applied if small numbers are involved in each frequency. Since we are comparing frequencies containing both small and large numbers, both the χ^2 and t tests were applied to all frequencies. (Pearson, 1914, p. 92; Yule and Kendall, 1937, p. 442; and Treloar, 1935, app., table III.)

TABLE 3
A Comparison of the χ^2 and t Tests Applied to the Four Frequencies.

	I and II	I and III	I and IV	II and III	II and IV	III and IV
P from χ^2 -----	0.03043	0.00497	0.39737	<0.000015	<0.000015	0.30935
2τ from t -----	0.00677	0.00036	0.18625	<0.0000002	<0.00019	0.20690

From the four frequencies there are six possible comparisons. Table 3 shows a comparison of the values obtained by the two methods. If our theories of sardine migrations are correct, we should not expect small tagged fish to move from southern California into British Columbia, Washington and Oregon waters within a short time interval. Furthermore, the large sizes should dominate the medium sizes in the north. A comparison of frequencies I and II bears out this contention but the number of individuals in frequency II are too few to make the curve very reliable. However, the t test indicates that the differences are significant.

Comparisons of curve II with III and II with IV indicate that during the summer the bulk of the large tagged fish from southern California were in regions north of the San Francisco-Monterey fishing grounds. The differences between these curves are highly significant. On the other hand, if the smaller tagged fish have not moved as far north as the British Columbia, Washington and Oregon fishing grounds they should be taken in the San Francisco-Monterey fall fishery. This is clearly indicated by the comparisons of curves I with III and II with III and the tests of reliability for these comparisons.

According to present theories of sardine migration the large fish from the north are expected to arrive in numbers off central California during the winter. These fish are thought to continue to southern California waters with the medium sized fish. We might expect then that the sizes of fish taken in the winter months at San Francisco-Monterey and San Pedro should be very similar. This is indicated by the similarities of frequencies I and IV and by the measures of reliability.

For the comparisons between the San Francisco-Monterey fall and winter frequencies, curves III and IV, the winter frequency should contain more large fish than does the fall frequency. This is true but the measures of reliability indicate that the differences are not significant.

Acknowledgments

The State Fisheries Laboratory of the California Division of Fish and Game is indebted to the Bureau of Patrol of the Division for their willing cooperation in making available to us their patrol boats, especially the *Yellowtail*, from which most of the past year's tagging has been done. To Captain Edward R. Hyde and the crew of the *Yellowtail* we want to express our appreciation for their able assistance. We are grateful to the many fishermen who have donated sardines for tagging purposes, and to those owners and employees of canneries and reduction plants who have cooperated in the recovery of tags. We appreciate the cooperation extended by the officials in British Columbia, Washington and Oregon who have exchanged tagging data with us and arranged for the recovery of California tags in their localities.

Summary

The migrations of the California sardine, *Sardinops caerulea* (Girard), along the Pacific Coast of North America are being studied jointly by Canadian, Washington, Oregon and California authorities. The present paper deals primarily with the work of the California investigations. From March, 1936, to June, 1938, 53,352 sardines have been tagged in California waters and 1054 on the coast of Lower California (Mexico). Already, these tags have yielded 1334 recoveries along a thousand mile coast line. Since tagged fish were usually released on or near the fishing grounds, most recoveries have been from fish caught soon after tagging in the same fishing region as tagged. However, 258 tags from southern California fish have been recovered in central California, and 30 in Oregon, Washington and British Columbia. Conversely, 10 British Columbia tags and one Oregon tag have been taken in California. In addition, 8 central California tags were recovered in southern California.

An internal or "belly" tag is used. It is a flat strip of nickel-plated steel, 19.05 mm. by 3.97 mm. by 0.63 mm. Each tag bears a serial number. Smaller tags are used for very small fish. The tag is inserted into the body cavity of the fish.

Sardine tags are recovered by means of electro-magnets placed in the meal lines of reduction plants.

TABLE 4—Continued
California Sardine Tag Recoveries, March, 1936—June, 1938

Sardines tagged by locality			Number of recoveries by region and season												
Date tagged	Locality tagged	Num-ber of sardines tagged	California 1936-1937 season				North of California 1937 season			California 1937-1938 season				Total number recovered from each lot tagged	Percent-age recovered from each lot
			Recov-ered at San Francisco	Recov-ered at Monterey	Recov-ered at San Pedro	Recov-ered at San Diego	Recov-ered in British Columbia	Recov-ered in Wash-ington	Recov-ered in Oregon	Recov-ered at San Francisco	Recov-ered at Monterey	Recov-ered at San Pedro	Recov-ered at San Diego		
Mar. 24, 1937	Newport.	1,030			10			1		8	1			22	2.14
Mar. 26, 1937	Newport.	797			22		3	1		11	6			44	5.52
Mar. 27, 1937	Newport.	680			3		2	1		30	13		2	51	7.50
April 20, 1937	San Quentin Bay	91													
May 9, 1937	Long Beach	389													
May 9, 1937	Long Beach	398													
May 9, 1937	Monterey Bay	1,492								6	4			11	2.83
June 9, 1937	Monterey Bay	1,211								3				18	4.52
June 16, 1937	Farallone Islands	554								3	2			6	0.40
Sept. 28, 1937	Farallone Islands	323								24	8			33	2.73
Sept. 28, 1937	San Francisco Bay	571								19	9		2	30	5.42
Sept. 29, 1937	Farallone Islands	671													
Sept. 30, 1937	Farallone Islands	348								40	16		1	57	9.98
Oct. 1, 1937	Farallone Islands	522								29	17		1	47	7.00
Oct. 1, 1937	Farallone Islands	522								19	3		1	23	6.61
Oct. 5, 1937	Monterey Bay	765								26	7			33	6.32
Nov. 2, 1937*	Monterey Bay	1,178								41	38			79	10.33
Nov. 5, 1937	Monterey Bay	557								5	7			12	1.02
Nov. 8, 1937	Monterey Bay	435								8	10			18	3.23
Nov. 9, 1937	Monterey Bay	662													
Nov. 9, 1937	Monterey Bay	899								3	4		1	8	1.21
Nov. 9, 1937	Santa Monica Bay	100									2			3	0.33
Nov. 29, 1937	Santa Monica Bay	785											3	3	3.00
Dec. 1, 1937	From Pt. Mugu to Pt. Dume.	413											16	16	2.04
Dec. 2, 1937	Catalina Island	587											10	10	2.42
Dec. 2, 1937	Santa Monica Bay	863													
Dec. 14, 1937	Santa Monica Bay	1,003											21	21	2.43
Dec. 15, 1937	Newport	598											2	2	0.20
Feb. 4, 1938	Newport	655											11	11	1.84
Feb. 7, 1938	Newport	1,062											18	18	2.75
Feb. 7, 1938	Newport	835											4	4	0.38
Feb. 8, 1938	Newport	214											61	61	7.31
Feb. 8, 1938*	Newport	386											8	8	3.74
Feb. 10, 1938	Newport	185											16	16	4.15
Feb. 10, 1938*	Newport												1	1	0.54

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REDUCTION PROCESSES FOR SARDINES IN CALIFORNIA ¹

By S. ROSS HATTON and GEORGE R. SMALLEY

California Division of Fish and Game

INTRODUCTION

From an insignificant beginning the reduction of fish and fish offal to scrap, meal and oil has become an industry of magnitude in the State of California. Not only has it contributed to an unprecedented expansion of the sardine fishery, but also it has kept constant pace with an ever improving and increasing fishing fleet. The value of this fishery has been attainable because of the ready market for reduction products, together with the advancement in the mechanical means of utilizing the maximum good from the raw product.

The methods of converting whole fish and fish offal into stable and portable articles of commerce will be described in the following pages.

HISTORY

The present development of the California reduction plants is in part the results of accumulative advancements made elsewhere, mainly on the eastern coast of the United States and in Europe. The history of this development is given briefly, as it makes possible a better understanding of the present day processes.

Foreshadowing the modern use of fish scrap as a fertilizer, the American Indians of the eastern coast are credited with having used whole fish, principally menhaden, to insure a better crop of maize, because the fish buried in the hills with the seed added plant nutrients to the soil. This custom persisted along certain parts of the middle Atlantic coast to, and even beyond, the year 1800, and in the Scandinavian countries and Iceland until 1899.

Following the use of green fish as a fertilizer came the supposedly accidental discovery that it was possible to obtain useful oil from the fish. Hogsheads were partly filled with menhaden, water added, and the recovery of the oil left to the putrefying action which soon set in. Frequent stirring was necessary to facilitate the liberation of the oil globules, which floated to the surface and were skimmed off. After the oil ceased to collect at the surface, the residuary mass was used as a fertilizer, the oil and "guano" thus obtained being utilized by the individual producing it, or disposed of to immediate neighbors. Although fertilizer is at present just one of the minor products of a reduction plant, the term "fertilizer plant" still lingers on in general parlance because of early associations.

¹ Submitted for publication, August, 1938.

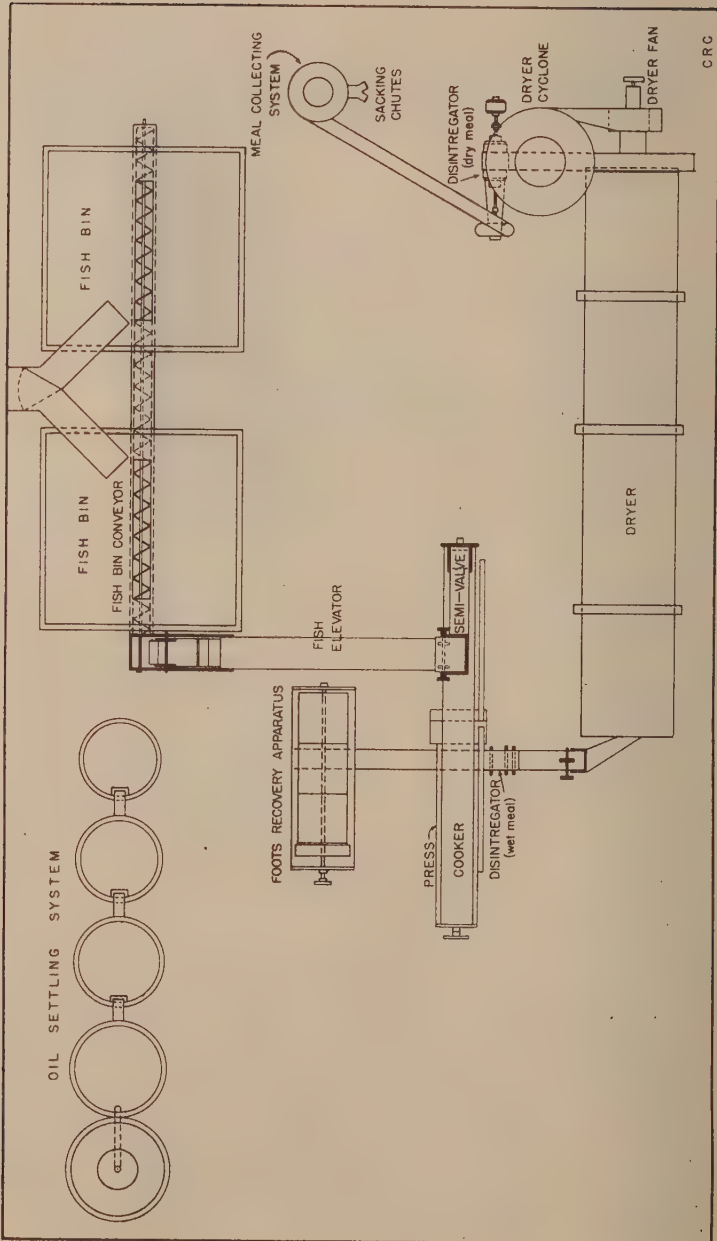


Fig. 129. Diagrammatic drawing of the layout of a sardine reduction plant.

The first improvement made in the foregoing process was boiling the fish in huge kettles, then placing them in casks as noted above. By 1830 the boiling of fish was general among the few farmers who attempted to bolster their incomes by this crude reduction method.

Beginning about 1850, the extraction of oil from menhaden, together with the preparation of fish scrap as a fertilizer and of meal as a stockfood, can be considered as an industry. During the period from 1850 to 1865, about 15 plants were built and operating, the majority of them in Maine. By this time steam cooking was used generally, a process which made a greater oil yield possible. Another distinct advancement was the use of presses to extract the oil, instead of the old skimming method. At first the cooked mass of fish was placed in a perforated wooden stave container and weighty objects laid on top for several days. Soon this method became obsolete with the introduction of hand lever presses; then the screw type of press was used, and in 1858 the hydraulic press was adapted to the industry, and a few years later was in general use.

Paralleling the mechanical improvements made in fish reduction processes was the increasing efficiency of the menhaden fishing fleet. The development of the purse seine and the adoption of the steam-driven fishing vessel gave encouraging indication of a dependable source of raw material.

The first menhaden oil produced was used as a substitute for, or to adulterate linseed oil in outdoor paints. This use dominated the oil market prior to 1865, when the product began to be used for currying or filling leather. Another early use of the oil was as a burning oil in the safety lamps of coal miners and in cordage manufacture. A European export market was established around 1875, where the oil was used in the manufacture of cheap soaps and as a sheep tick repellent. Present day industries find many and varied uses for fish oils; they are utilized largely in the manufacture of soap, paint and varnish, linoleum, felt-base paper industries and waterproof fabric industries. Lesser amounts are used in the tanning of leather and in making artificial leather, for quenching steel, for insecticide sprays; in the manufacture of candles, rubber substitutes, printer's ink and textiles; and as a constituent of core oils. Rather more recent developments tend to show that the oil can be used as vitamin concentrates in human and animal nutrition; likewise by hydrogenation the oil is finding uses as lard substitutes, lubricating greases and powders, and buffing compounds.

One of the persistent obstacles in the path of the developing industry was the disposal of the meal or scrap. Because of the high moisture content the press residue had to be used almost immediately; otherwise decomposition set in and made it practically valueless. The first attempt to insure stability and portability of the meal was to dry the press cake on platforms in the sun. This was in 1853. While the method by no means solved all the difficulties, it was a definite improvement.

Another method of preparing the meal for shipment before the advent of artificial dryers was acidulation by sulphuric acid. The action of the acid "fixed the ammonia, prevented fermentation, and dissolved the bones." This method of treating with acid was common

in the Maine plants, whereas in the South sun-drying, when weather permitted, was the common practice.

Although the need for artificial drying was recognized early, it was not until 1880 that dryers came into general use in the menhaden plants. Hot air and steam dryers were both used and contributed greatly to the stability of the industry. Both types are in use today and will be described on subsequent pages.

The use of fish scrap or meal as an animal food has only in recent years become of importance, although this use was anticipated at an early date, in various parts of the world, by feeding stock whole fish. Extensive studies in the United States and Europe around 1875 showed the value of such fish products for stock feeding. However, prejudice and custom combined to prevent the general use of the meal prior to the World War.² The high price and actual scarcity of feeds at that time forced the farmers of America to use feed materials which had been neglected previously. A stimulated demand for fish meal in preference to the coarser scrap accelerated the installation of machinery necessary to produce the more desired article, so that at present the bulk of the dried product finds its way into various mixed rations for poultry and live stock.

Gradual development of the reduction processes followed, until about 1914, when plants became essentially as we know them today. Bucket elevators, automatic conveyors, continuous steam cookers, hydraulic presses, artificial dryers, and other forerunners of the most modern of present day equipment were in general use. The industry is, however, by no means stalemated, for continued improvements and changes are resulting in an ever more economical operation and improvement of its products.

It should not be inferred from the above account that the industry in California has not undergone a period of development and advancement. Independent, to a large extent, of the much earlier established industry in the East, California reduction methods have become today as mechanically efficient as those in use in other places. Here again is an interesting and instructive developmental period to be considered.³

Fish offal, rather than whole fish, was first used in California for the production of scrap; the offal was handled as a sideline to the regular treatment of slaughter house tankage. Beginning about 1900, the Excello Grease Company, located in Butchertown, San Francisco, obtained fish offal from the fresh fish markets of the city and produced a fish scrap which was disposed of to the Hawaiian Fertilizer Company and blended with the latter's product obtained from whale meat to produce a commercial fertilizer. The offal was cooked in a large steam vat under a few pounds pressure. After each batch was cooked, the

²The first attempts at using fish meal for stock feeding were discouraging because of the high oil content of the meal available at that time.

³The authors are indebted to the following for much of the information contained in this article, especially in the following section: Messrs. Max N. Schaefer, K. Hovden, Fred Mullins, Harry Berggen, William Baumbacker and George Harper. To this roster of men who were instrumental in establishing the reduction industry in California, we would like to add the names of Messrs. Wilbur Wood and F. E. Booth, although we had no opportunity to contact them personally. We are also indebted to many reduction plant foremen and workers, and also to the representatives of the various companies engaged in the manufacture of reduction plant machinery—a list too numerous to accord individual recognition. Lastly, we wish especially to thank Mr. Ralph Classic and Mr. Harry Berggen for many helpful criticisms of the manuscript.

mass was removed to a blanket press (a hydraulic press in which a "blanket" served as the straining surface) to remove the moisture, and the press cake was further dehydrated in a direct fire dryer.

A few years later the Miller and Lux Company, operating a slaughter house in San Francisco, began using fish offal to make fish scrap. Their product was mixed with dried meat offal and marketed as a fertilizer. It is very probable that the use of fish offal became a common sideline in many meat packing establishments where the raw material was available at this time.

The first venture in California made for the sole purpose of reducing fish was at McNear's Point on San Pablo Bay in 1914. Max N. Schaefer constructed a plant costing \$15,000, primarily for the purpose of handling salmon offal from the G. W. Hume cannery at Benicia. Considerable buck shad were also used during the season. Strangely enough, about the only fish used throughout in the round were sharks and skates, which were easily obtainable in the Bay.

This plant differed in several interesting details from the modern plant. Cooking and drying were accomplished in one operation by means of the steam-batch dryer.⁴ The green material to be used was placed directly in the dryer and heated under partial vacuum until sufficiently dry. The dryers, in actual operating details, were very similar to the present day batch dryers; for those in Schaefer's plant were long steel cylinders (18 feet by 4 feet), mounted on two end rollers, with the cylinder encased in a steam jacket having controllable feed lines. During the drying, a partial vacuum was maintained by means of a small vacuum pump. The cylinder revolved slowly (nine revolutions per minute), tumbling and spreading the material throughout the length of the dryer; it was equipped with small flights projecting inward from the cylinder to assist in mixing the material. Two counter-balancing heads served for feeding and discharging. A dryer of the above size is capable of handling 3500 pounds of material in 3½ hours when the customary temperature of 160° F. is maintained during the process.

Oil was extracted from the "crackling" or unfinished meal which had been cooked and dried by the gasoline extraction method. This process has been described by Scofield (1921) and is here quoted:

"Extraction tank

The extraction tank is a heavy cylindrical steel tank about nine feet in diameter and about fourteen feet high. The tank is filled through a door in the top to within eighteen inches of the top with the dry unfinished meal. Gasoline is then sprayed in from the top through a perforated pipe till the tank is filled with gasoline sufficient to cover the meal. The tank full of meal and gasoline is then heated by introducing steam at the top of the tank. The heat is said to be about 325 degrees and is continuous for an average of about eight hours. The gasoline begins to take up the oil of the fish meal even before the meal is thoroughly heated, so that the process of draining off the mixed gasoline and oil is begun soon after the steam is introduced. The bottom of the tank is a sheet of steel perforated to allow liquid to drain through it. Under this metal sheet there are alternating layers of charcoal and gunny sacking to catch and hold particles of meal, so that the liquid may be drained off as pure as possible. After this oily

⁴ Dryers may be separated into the batch type and continuous type. In the first, each charge of the dryer is finished before any additional material is introduced, and in the continuous type, charging and discharging are one continuous operation.

gasoline is drained out, the tank is again flushed with a fresh supply of gasoline, which is also drained off. A small door in the side of the tank, even with the metal floor, is then opened and the meal pulled out.

"Recovery of oil

The liquid drained from the extraction tank is carried by pipe into a smaller tank called the evaporating tank, which is about 12 feet long and 5 feet in diameter. It is provided with a large steam coil capable of heating the liquid to 300 or 325 degrees. The heat volatilizes the gasoline and a pipe at the top of the tank carries off the gas thus formed. After about four hours practically all the gasoline is driven off, leaving only the fish oil remaining in the tank. If much gasoline is left in the oil and the oil is later refined, a serious explosion is apt to result, so that it is essential to drive off all the gasoline possible. The oil is then blown out of the tank by steam pressure and conducted by pipe to a storage tank. The oil is later deodorized by heating to about 600 degrees, which also removes practically all of the moisture and other volatile impurities. The oil is then ready for shipment to the paint manufacturer.

"Recovery of gasoline

The volatilized gasoline escapes from the evaporating tank in a pipe that is run through a condenser or coiled pipe in a bath of running cold water. Ocean water is particularly good for cooling the condenser pipe. The condensed gasoline drains into a storage tank and is ready for use again in the extraction tank."

The two plants using the forgoing described method of oil extraction discontinued operation in 1920.

In addition to the plant just described, there is another phase to the beginning of the industry that has continued uninterrupted up to the present time. From the outset of the fish canning industry in California, offal disposal became a problem; and, prior to the installation of reduction units, the waste from the canning lines was loaded on barges and dumped several miles at sea. The hygienics of this procedure became a hotly debated problem to civic authorities, and at times a severe financial drain to cannery operators. It was not uncommon for the cost of such disposal to reach \$3.00 a ton. Disposal costs and the conviction that the offal could profitably be used were the incentives that started an industry which has since become of considerable magnitude.⁵

Reduction of offal was begun on an experimental basis at the F. E. Booth Company plant at Pittsburg in 1910. The first unit installed was a so-called bottle digester of eastern manufacture. This steam-jacketed bottle unit was stationary but was equipped with a center shaft and a series of paddles. Raw material to a capacity of 750 pounds was placed directly into the digester and cooked, while being constantly agitated. After the mass was sufficiently cooked, the water and liberated oil were drawn off into a series of settling tanks, while continued heat applied to the mass removed still more moisture. From the container, the material was placed in a blanket press for additional moisture removal and oil recovery. Drying was completed by solar radiation.

The success of this venture led in 1912 to the installation of a Dayton Garbage Dryer of the type commonly used in municipal

⁵ The World War, with the ensuing demand for canned goods, made reduction units more or less an actual necessity. The prevailing prices of meal and oil at the time were also incentives to the expansion of the industry. Meal sold for \$60.00 a ton, and oil for \$1.10 a gallon.

garbage disposal plants throughout the Middle West. Essentially, the apparatus was of the same general construction as our present day steam-batch dryers, the greater length being vertical rather than horizontal, however. The cylinder, 5 feet in diameter and 7 feet high, was stationary, but the material being dried was kept in motion by paddles, connected to a center shaft. This dryer was installed in the Booth Company plant at Monterey.

In the same year (1912) the screw press was first installed and used in a California reduction plant. This unit was made by Toulouse & Delorieux Company of San Francisco and had previously been used as a wine press.⁶ (A solid bronze, double screw press, originally made as a wine press, is at present still giving satisfactory service in a reduction plant.)

Credit must also be given to the F. E. Booth Company for equipping and operating the first floating reduction unit in California for cannery offal, when, in 1913 and 1914, the *Newark*, a converted lime-kiln barge was used for this purpose for one season at Monterey and one at Pittsburg. Her equipment consisted of an open steam vat cooker, a hydraulic press and a steam-batch dryer.

The next attempt to effect improvements was the installation (1915) in Monterey of a direct flame rotary dryer. Oddly enough, the shell was constructed of cement and it was discarded after one season.

Up to this time cooking of the offal had been done in open steam vats or in a digester as mentioned above; however, in 1915 F. E. Booth designed and installed in Pittsburg the continuous spiral cooker, which differed only in minor details from present day cookers.

In 1915 Schaefer established his second California plant, this one at Monterey. His raw material was obtained from the several cannerys operating there at the time and was handled by the same method as described elsewhere.

The first meal produced in California from sardine offal was sold unground,⁷ because the hammer type disintegrators (dry meal) were not in use prior to 1916. Like the majority of fish reduction units, the hammer mill was also adapted to fish meal processing from types used in other manufacturing lines.

By 1916 the mechanical means of utilizing fish offal to produce meal and oil had in general been perfected to a surprising degree, at least as far as the individual units were concerned. In the following year the first continuous reduction installation in California was completed and operating in the Booth Company plant at Monterey. This

⁶As suggested by Scofield (1921), it is very probable that the screw press was first developed in the olive oil extraction industry.

As a humorous insight into some of the mechanical difficulties encountered in these first presses, it is worth recalling that the mentioned firm was invariably referred to as "Too-loose and Too-tight." The name was the operators' way of expressing an opinion that the presses were never correctly adjusted, and no two adjusted alike. As the effect of cooking and condition of the offal prior to cooking came to be better understood, this difficulty was somewhat removed. But perhaps the most important step in converting wine presses to use in fish reduction was a change in speed of the two screws. By retarding the press screw to a speed less than that of the hopper screw, much more satisfactory results were obtained.

⁷The early fish meal producers met a prejudiced market until the public became familiar with their product. Petaluma poultrymen, a group which made up one of the first established markets, had previously tried salmon meal in their mixed rations. This Alaskan product had a very high oil content, and for feeding purposes gave unsatisfactory results.

was a decided improvement over any existing plant, as it effected a considerable saving in operating expense and greatly increased the plant capacity.

With the exception of the dryer, this plant differed but little from present day units; for conveying screws and buckets, spiral cookers, screw presses, hammer-type disintegrators (dry meal) were all essentially modern. The dryer consisted of two stationary, long steel drums, one placed directly above the other; both were surrounded by firebrick with the ends resting on a firebrick arch. The firebox was beneath the lower drum, with vents leading from the box proper to spaces built around each drying unit for the conduction of the heated air. At one end of each tube was a cyclone fan forcing the air in the same direction as the meal was moving. The fans were so placed that they had no connection with the heated air from the furnace, but served only to spread auxiliary heat from the surrounding firebrick and helped to pull the meal through the length of the tube. A center shaft equipped with projecting paddles to agitate the material traversed each tube. Meal entered the uppermost tube, was carried throughout its length by the forward throw of the paddles and the air current created by the fan, then fell into a hopper feeding the lower tube and was discharged at the opposite end. This two-drum unit had a capacity of two tons of press cake per hour.

In the following year (1918) several canneries installed reduction machinery patterned after the Booth unit. Among them were the International Packing Company at San Pedro and Steele Bros. at San Diego. At the same time there were six operating plants in Monterey, some of which were established prior to 1918. Some early operators in Monterey were the K. Hovden Canning Company, J. Madison of the Pacific Fish Company and George Harper of the Monterey Canning Company.

About 1920 the wet meal disintegrator, a so-called nutrition mill to be described later, was introduced.

From that time to the present the handling of meal has followed rather conventional lines, the greatest changes having taken place in the dryers, where the earlier beneficial developments in these units are ascribed to eastern ideas.

From the beginning the press liquor has been handled by the flotation system, the method being practically the same as that used today. One interesting change was that the first settling tanks used (generally six) were made, for economy of floor space, quite high and narrow. Considerable difficulty was experienced in separating the oil from the water-oil emulsion just beneath the flash oil layer. It was a common practice to add salt to the mixture, for the greater weight of the salt water aided the separation. However, when tanks were used in which the diameter was greater than the height, a much better separation was obtained.

In 1927 the first centrifugal system (to be described later) for separating the press liquor into its components was installed.

Additional equipment for oil recovery is a recent innovation. The foots machine (so-called because it supposedly represents the foot or end of the recoverable solids) came into general use in 1932, although this device was anticipated some years earlier by a similar

machine which was never widely adopted. The vibrating screen has been in use for only two or three years.

Prior to 1930, the only material available for reduction in any amount was offal from the canning lines. In that year, by a legislative act allowing reduction of whole sardines under permit, an impetus was given to the industry which may be realized from the number of plants operating today: 70 at the time of writing (1937-38 season).

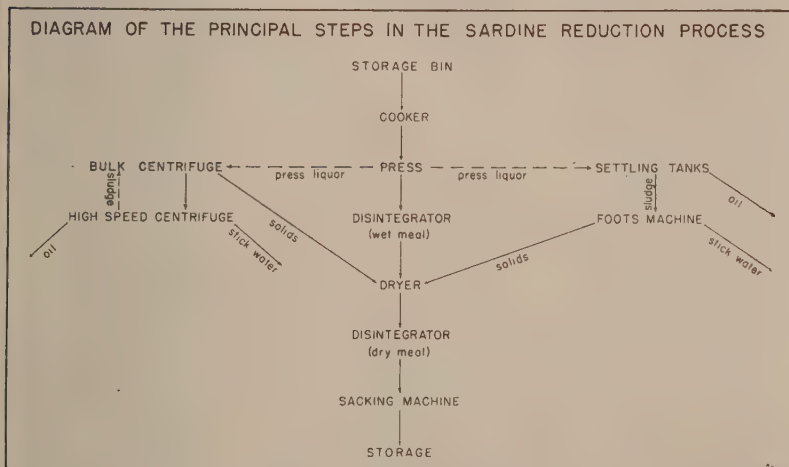


FIG. 130. The principal steps in the sardine reduction process. The solid arrows indicate successive steps; the dashes indicate alternative steps (the press liquor is treated either in settling tanks or in centrifuges).

PROCESSING UNITS

As an aid in following the continuity of the reduction process, figure 130 has been prepared, showing the successive steps in the treatment of the raw material. Alternate steps are indicated by dotted lines. The relative positions of the various units are shown in the outline drawing of a generalized plant in figure 129.

The following descriptions of reduction machinery in use today apply only to one installation, and the installations are not necessarily from the same plant. It should be understood that all measurements, speeds, temperatures, etc., may, and certainly do, vary according to plant capacities and personal ideas of the operators; likewise, there may be considerable difference in detailed items of construction in the same units of different manufacture.

Cookers

Cookers are of one general type, descriptively called the continuous spiral worm cooker or digester. A cooker is essentially a long steel tube, equipped with a conveying screw worm, which carries the material to be cooked past a series of live steam jets, supplying steam at 8-inch intervals from a manifold beneath the cooker. In some cookers the jets are staggered, every other jet entering above the bottom

of the cooker shell. A number of Eastern plant operators prefer, in addition to the jets along the bottom, a hollow shaft jet arrangement, wherein steam is discharged through small continuous openings in the revolving shaft.

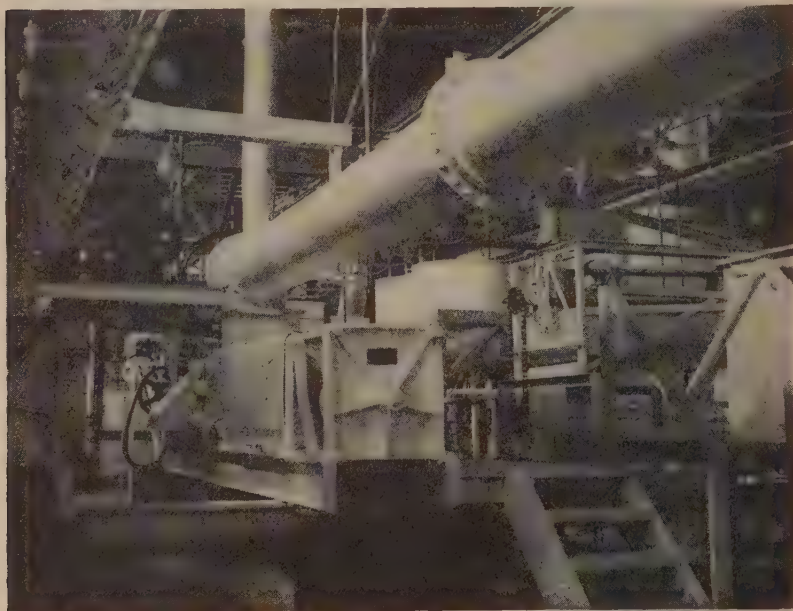


FIG. 131. A spiral cooker and directly below it, in the square housing, the screw press. As may be seen on either cooker, the steam jets, in this installation are staggered, and the manifold is to one side, rather than below the cooker. The view is toward the discharge end of the press. Photograph by E. L. Macaulay.

The size of the cooker varies according to the press capacity; extreme lengths are 30 to 100 feet, with outside diameters of 17 or 19 inches, allowing a 16- or 18-inch screw, as the case may be.

The fish are conveyed from the bins by a bucket conveyor, each bucket holding 6 to 10 pounds of fish, which are delivered into the semi-valve, allowing the entrance of the material into the cooker without loss of steam pressure. The material is then carried forward by the slowly revolving screw, past the numerous steam feeds in the bottom of the shell and after 20 to 25 minutes of cooking arrives at the discharge end. The pressure (and subsequent rate of cooking) varies from 3 to 25 pounds, the pressure being determined by the nature of the material to be handled; for instance, fresh solid fish require more pressure than stale fish. At times, when the operator wishes to hasten the process, the speed of the spiral worm, as well as the steam pressure, may be increased. However, thorough cooking is essential at all times to free the oil globules and to obtain the maximum oil yield. Over-cooking is to be avoided also, for when the fish are too soft, pressing is more difficult.

Some three feet from the discharge end of the cooker, the bottom half of the solid cooker shell is replaced by a screen with a bleeder to carry away what oil and moisture may have separated from the mass during cooking.

Presses

The next step is pressing the cooked fish to remove as much of the oil and water as possible. The pressing unit is located directly under the cooker, because it is necessary that the material be pressed before any cooling of the mass takes place; so the fish are received in the press hopper as they emerge from the discharge end of the cooker.

The press consists of an 8-foot continuous cast steel worm, forming the horizontal axis, which is surrounded by a cylindrical screen. The screen is divided into two sections, each with two pieces of screen, top and bottom. The first section, known as the hopper screen, is 24 inches long, with 32 holes to the square inch. The second, or press screen, is 64 inches long with a screen size of 64 holes per square inch.⁸ Flights on the worm are machined to fit closely against the inside of the screen, especially at those points directly beneath the curb-slats, which form reinforcing collars around the outside of the screen

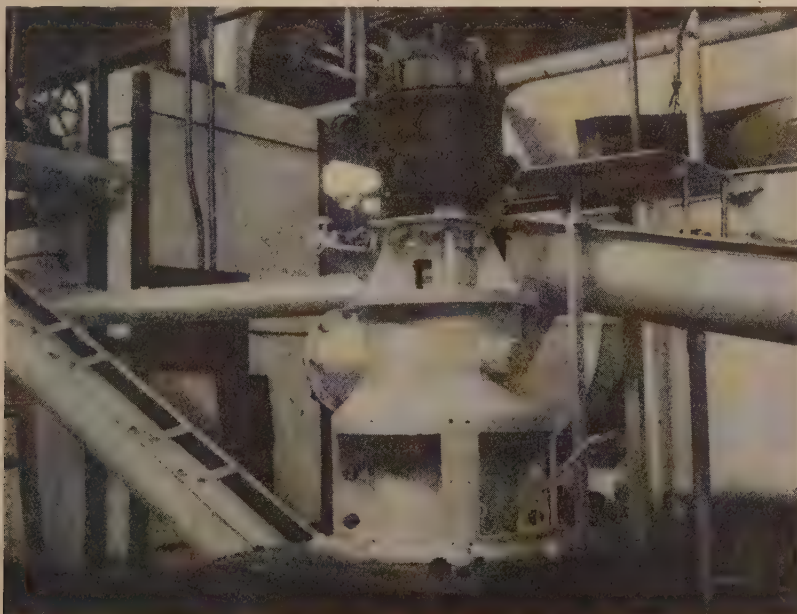


FIG. 132. The vertical wet meal disintegrator. In the left background is part of an 'L' furnace, and the round tube in the left center is a water-jacketed meal conveyor. Photograph by E. L. Macaulay.

that may be adjusted to make regulation of the distance between the flights and the screen possible. The worm is cone-shaped at the dis-

⁸A press of different manufacture from the one here described has holes of uniform size throughout.

charge end, fitting closely against the beveled end of the press casting.⁹ Pressure is exerted as the continuous flights carry the mass against the restricted area (core block) between the cone and its beveled counterpart. The position of the cone and, hence, the discharge opening and the pressure may be varied. Motive power for both the cooker and the press screw is supplied by an electric motor of 20 to 25 horsepower, and the speed of the two units is synchronized.

Moisture and oil are forced from the material and collected in drip pans below the press. The subsequent treatment of the press liquor will be described later.

Wet Meal Disintegrator

The material from the press, known as press cake, is led by a screw conveyor into the wet meal disintegrator (also called hasher, beater and fluffer), which is designed to pulverize it completely before it enters the dryer. The speed of the drying process and the economy of operation are furthered when the material at this stage is finely divided.

One type of disintegrator is essentially of the same construction as the common household meat grinder (nutrition mill), consisting of a worm which forces the meal against a revolving knife, which cuts against a flat steel plate, perforated with holes of one-inch diameter.

Another type of disintegrator, the vertical hammer type, consists of a battery of hammers enclosed by a heavy screen. The hammers are short, wedge-shaped castings, rigidly mounted at regular intervals on a vertical shaft that turns at a speed of 3600 revolutions per minute, "whipping" the meal and literally throwing it through the surrounding screen.¹⁰

In a very similar disintegrator, of different manufacture, solid sheets surround the hammers, the latter fitting closely against the sheets. As the material is thrown outward by the revolutions of the shaft, it is pulverized between the sheet and the ends of the hammers; it is then collected in a hopper directly below and conveyed to the dryer.

Dryers

The adaptation of artificial dryers to the production of fish scrap and meal was one of the most important steps in the development of the industry. During the years of expansion this unit became of increasing importance, with a resulting variety of types, and even modifications of the general types being produced. The effect of drying

⁹ The diameter of the worm continuously increases toward the discharge end, with a corresponding decrease between the outer and inner diameter of the flights. As the flights near the cone end, their angle of inclination more nearly approaches the vertical; thus as the mass nears the discharge end, it travels more slowly and under greater pressure. In some presses the worm is divided into two sections, constructed so that the sections may be turned at different speeds. Increasing the revolutions of the section near the intake over that of the following section has a comparable effect to that produced when the angle of the flights is decreased in the last section. The majority of the first presses used were double screw. (See footnote 6.)

¹⁰ The screen is 18 inches in diameter, 18 inches deep and $\frac{1}{4}$ inch in thickness. The holes are $\frac{3}{8}$ inch in diameter.

Each hammer is 6 inches long and $\frac{1}{2}$ inch thick; at the point of assembly to the center shaft they are 2 inches wide and are wedged to $1\frac{1}{2}$ inches at the free end. They are spaced at 2-inch intervals on the shaft and are "staired," i.e., no succeeding hammers are in alignment. The hammers of some units are not rigidly mounted to the center shaft but are movable along the horizontal plane.

upon the finished product is a carefully considered factor in the successful operation of a plant, for complete drying is of foremost importance; but at the same time, scorching and burning of the material must be avoided. Likewise the loss of heat-labile nutritive elements must be kept at a minimum.

With the increasing tendency of plants to locate close to an available labor supply, especially when reduction is carried on in conjunction with canning, the odor problem is also considered in the selection of a dryer. Most of the gases which have given to reduction plants a certain (and in some cases a justifiable) olfactory stigma, arise from the meal during drying. So, many of the alleged points of superiority of one type of dryer over another are based upon this one factor.

The variety in the types of dryers reflects the importance of careful handling at this stage of the process, as well as the diversity of opinions as to how this need may be best satisfied. Though each type of dryer in use can be assigned to one of several general types, many individual operators have had their dryers constructed according to personal specifications. Comparative merits of the different dryers are highly controversial; for this reason, the authors have avoided writing anything that might be interpreted as indicating a personal preference.

Steam-batch dryer

The first dryer adjusted to fish reduction needs was the steam-batch dryer, a form of which was described in a previous section. In connection with this dryer it should be recalled that raw fish were placed directly in the dryer, and the oil extracted later. This method has been found practicable only when the material to be handled was of very low oil content; the rather high oil content of sardines requires cooking and pressing first.

A modification of the first mentioned steam-batch dryer, the agitator type, consists of a stationary cylinder, 5 feet in diameter by 20 feet in length. The interior of the dryer is fitted with a large shaft running from the feed to the discharge end, with specially designed arms and paddles attached to mix thoroughly, agitate and convey the material through the heated interior of the cylinder. A fixed temperature is held in the cylinder by a surrounding steam jacket, where a steam pressure of 100 pounds is maintained. In a dryer of the given size, at the given pressure, 1500 pounds of dry meal may be delivered in three hours. The dryer shaft and paddles are clutch-controlled; and, by reversing the shaft, the meal is delivered at the discharge door in the lower section of the cylinder head. Such dryers may or may not be equipped with a spray condenser and a vacuum pump.

The dryers of this type are used in a series; that is, from six to twelve dryers are necessary in the average plant, the discharge from each of the units in the series being picked up by a common conveying screw and carried to the grinder.

Continuous steam rotary dryer

Another application of the steam drying principle has been utilized in the steam rotary dryer. In this form, a cylinder, 56 feet long and 6 feet in diameter, is mounted on two or more sets of trunnions. Running the length of the inside of the cylinder are 74 steam pipes,

placed in circles concentric and adjacent to the dryer shell. Four-inch pipes are near the inside of the dryer, with 2½-inch pipes placed next to the shell wall so as to leave an open space about 4 feet in diameter in the center of the cylinder. A steam pressure of 70 pounds

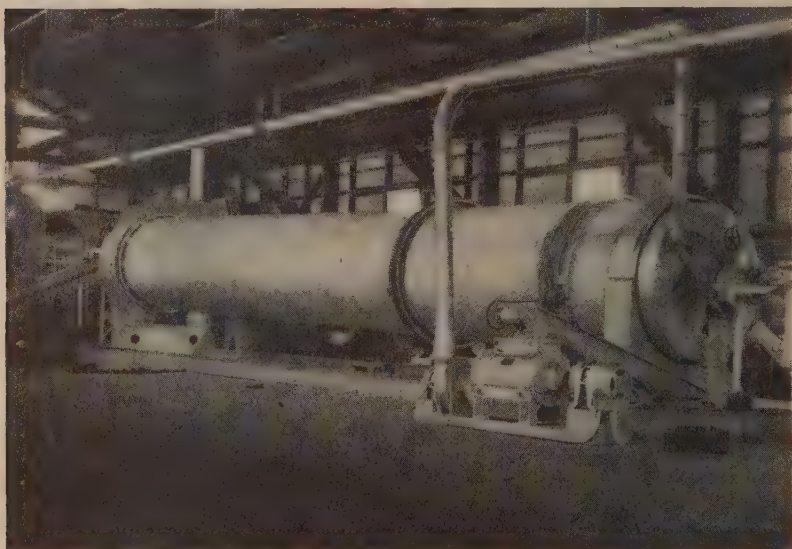


FIG. 133. A continuous steam rotary dryer. The longer overhead pipe is the steam feed pipe entering the cylinder through a control valve. The points of attachment of the inner steam pipes may be seen on the right end of the dryer. In the right foreground is the dry meal disintegrator, showing the screw conveyor leading from the dryer, and also the blower which forces the ground meal through the upright tube that leads to the sacking chutes. Photograph by S. Ross Hatton.

is maintained within the pipes, which results in a temperature of 242° F. Meal enters the slowly revolving (7 revolutions per minute) dryer and is tumbled over the pipes and through the heated atmosphere. A slight inclination of the cylinder is sufficient to move the meal to the discharge end. When meal first enters the dryer, it takes from 25 to 30 minutes for the dried material to appear at the discharge end; however, with a continuous flow of meal, the drying time is shortened to about 20 minutes at which rate 7300 pounds of wet meal may be handled per hour.¹¹ The vaporized moisture from the material is removed at the intake end by a cyclone fan.

¹¹ The following information is added to clarify the data relating to capacities of the various units, and it may be used where conversion factors are desired. These factors are approximations only, and vary markedly according to the plant, season and locality. (Clark, 1937.)

One ton of fish will yield from 40 to 47 gallons of oil. One hundred and seventy gallons of press liquor are obtained from each ton of fish, consisting of 12 to 16 per cent recoverable solids and 23 to 27 per cent oil. The meal ratio (number of tons of raw fish required to produce a ton of meal) is a fairly constant factor, being about 5½ or 6 to 1. The press cake contains about 50 per cent moisture, and after the drying process the amount of moisture is reduced to 8 or 10 per cent.

Semi-super heated steam dryer

In contrast to the dryers previously described, the furnace of a semi-super heated steam dryer is built in connection with, and forms a conspicuous part, of the installation. The furnace is an L-shaped structure of firebrick (9 x 12 x 12 feet). One wing serves as a mixing chamber for steam and hot air; the other wing is the firebox proper. Between the two chambers is an arch of firebrick, with a number of bricks omitted to allow for the passage of heated air into the mixing chamber, where steam is also introduced and mixed with the air from the firebox to produce a temperature of about 500° F.

Piercing one wall of the furnace and abutting closely against the arch is a small, rotating cylinder, which in turn enters the head of the conventional large rotating cylinder. The other essential part of the dryer is a large cyclone fan with damper control.

The meal first enters the mixing chamber in a water-jacketed screw conveyor. This cooling device is necessary to prevent the meal

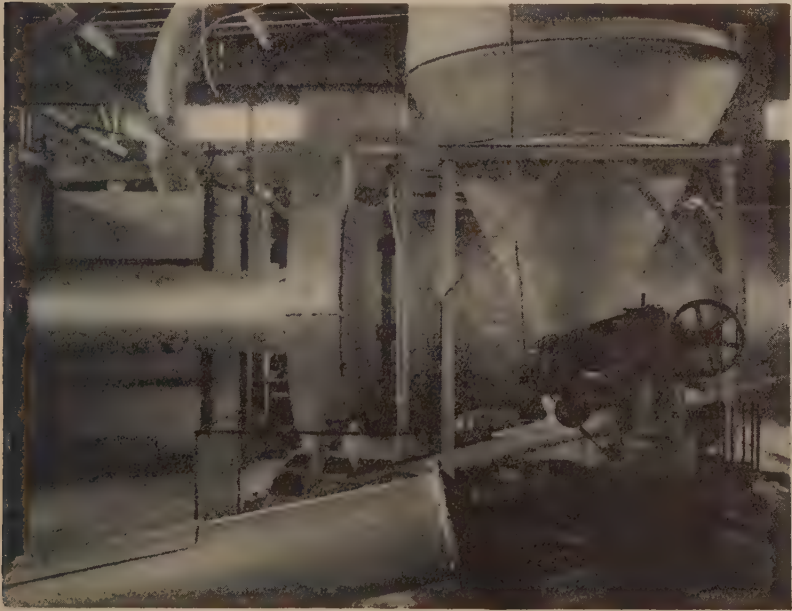


FIG. 134. A semi-super heated steam dryer. On the left is the "L" furnace and connecting horizontally with it the first and smaller drying tube entering the large drum. The collar at the point where the two tubes join houses the cyclone fan and its vents. The large funnel at the right and the machinery and conveyor tube in the foreground are part of the canning equipment. Photograph by E. L. Macaulay.

from burning at this point as well as to protect the conveying tube from the high temperature. From the conveying tube the meal enters the small cylinder (3 feet in diameter and 24 feet long). Some 14 feet from the arch, the small tube pierces the head of the larger one and

continues inside it for 10 feet; so that the dryer is essentially a tube within a tube, and, as the material in each tube travels in opposite directions, the same drying area is maintained as in the longer, single-tube dryers. Within each tube are small projecting baffle plates with an almost neutral throw, *i.e.*, the meal is thrown neither forward nor backward. After traveling the length of the small tube, the meal falls into the larger one; it then goes in the opposite direction and is discharged at the end where it first entered the drying unit.

The meal is moved along its course by the large cyclone fan, which also draws the vaporized moisture and spent gases from the chamber. It is interesting to note that when any particle of material has lost sufficient moisture, it is almost immediately carried to the discharge end, regardless of its position in either tube; but the heavier, moisture-laden particles continue until they are likewise removed by the air current. It takes the main mass from 20 to 25 minutes to dry. The capacity of this installation is 10 tons of press cake per hour.

Direct heat dryer

This type of dryer is somewhat similar to the above, consisting of a furnace built in connection with a large steel cylinder, and a cyclone fan. The furnace is of steel, cylindrical in shape (55 inches in diameter and 12 feet long) and lined with firebrick. Between the furnace and the drying chamber is a firebrick arch, with perforated walls for the passage of the heated air into the cylinder. The arch is removed sufficiently far from the combustion chamber to prevent the flames coming into actual contact with the meal.

The dryer proper is a long steel tube (4 feet in diameter and 53 feet long), mounted on two sets of trunnions, which connects directly with the furnace behind the arch. Meal enters through an overhead hopper or on an underfeed screw conveyor. On the inside of the dryer are baffle plates, or spiral shelves, which serve to drop the material continuously through the heated air as the drum slowly revolves. A large cyclone fan moves the dried material to the discharge end and removes all spent gases.

About twenty minutes are required to dry the meal when the temperature in the dryer is 195° F. and the capacity of a dryer of this size at this temperature is 15 to 20 tons of press cake per hour.

Grinder (Dry Meal Disintegrator)

From the dryer the meal, which is now nearly processed, is conveyed to the grinder for final sizing before sacking. This unit resembles the wet meal grinder so closely that it may aptly be described by comparison. The most notable difference is that the dry meal grinder is horizontal in position; consequently the meal enters at one side of the hammers, rather than directly above them. The hammers are also differently shaped, being trapezoidal instead of wedge-shaped, and shorter than the others described. The hammers, attached to a center shaft by pins, are slightly movable in the vertical plane and surrounded (except at that point where meal enters) by a screen with openings $\frac{3}{8}$ inch in diameter.

An integral part of the dry meal grinder is a cyclone fan situated at the end opposite the driving motor. As the meal is forced through

the screens, it is picked up by the cyclone fan and conveyed to a storage bin just above the two sacking chutes. Extending from the grinder is a 10-inch conveying tube which goes upward, along the ceiling, and then down to some convenient point where the actual sacking is done. In the majority of plants, sacking, weighing and sewing are done by hand, whereas others are equipped with automatic sackers.

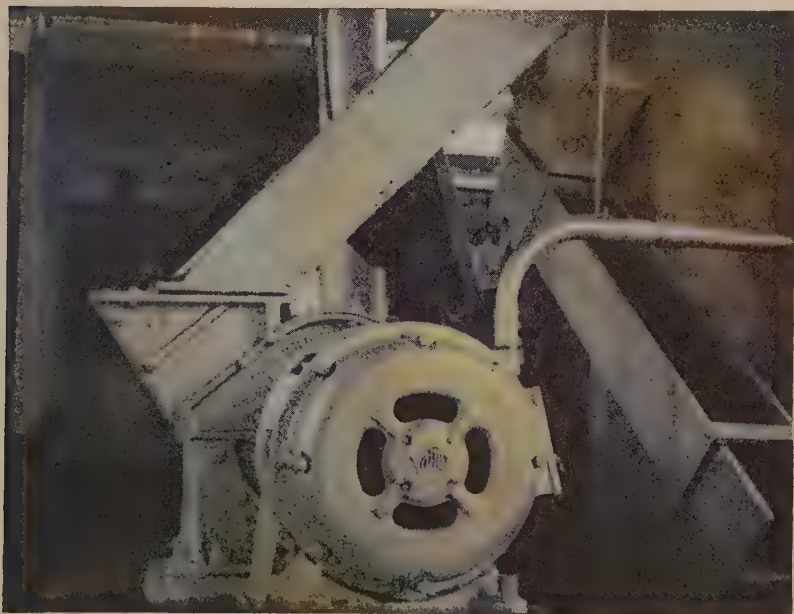


FIG. 135. The dry meal disintegrator, showing in the center background the tube that conveys the meal to the sacking chutes. Suspended underneath the conveyor feeding the disintegrator is the coil of an electro-magnet for recovering sardine tags. Photograph by E. L. Macaulay.

Floor Curing

Some plant operators subject the meal to a curing process before sacking. This consists of spreading the material to a depth of about 6 inches over a suitable surface for a 24-hour period. During this time the meal is turned at intervals, after which it is ready for sacking. This additional treatment supposedly gives the meal a lighter, better color and removes any possibility of its caking in the sack because of "sweating."

The spreading is accomplished by a reversible screw conveyor running the length of the curing room, where numerous trap or sliding doors along its length permit the material to be deposited on the floor below. After curing is completed, the meal is shoveled into a movable accessory conveyor to enter the overhead conveyor, whence it is taken to the sacking discharge. Some few years ago spreading was a general procedure in all plants, but the advent of more efficient dryers has largely removed the necessity of floor curing.

Separation of Press Liquors

We return now to the liquors which were separated from the mass during cooking and pressing. For every ton of fish handled, approximately 170 gallons of liquor are obtained, which consists partly of condensed steam added during the cooking, the natural oil and water content of the fish, and flesh particles which were forced through the apertures of the press screen. Economy of operation requires a nice separation of this liquid into its marketable oil and solids.

In contrast to the fairly standardized way of handling the meal, oil recovery is effected in a number of ways, many of which are recent introductions and others still in the experimental stage. Regardless of the methods employed for separation, they all work on one principle; the different specific gravities of the components of the press liquor allow their separation by simple flotation (settling tank system) or, if the force of gravity be superseded by centrifugal force, the same principle still operates. The respective levels of these different components are free oil on top, oil and water emulsion with some suspended solids next, then waste water, and solid particles on the bottom.

Settling tank system

The majority of California plants use the settling tank system for oil recovery, though vibrating screens and centrifuges may or may not be used in conjunction. Generally five tanks are used, the first being the largest and also the highest; the others are decreasingly smaller and lower, so that a continuous flow from one tank to the succeeding one is possible. Each tank except the last is equipped with an adjustable overflow regulator to maintain a continuous flow regardless of the amount of liquor to be handled. Liquor from the press and cooker is introduced into the first tank, and, by the time it has risen to the discharge opening, a primary separation has already taken place; thus, the next tanks receive free oil (flash oil) in addition to some water and solids, although the great part of the solids is retained in the first tank. Each tank in the series is filled to overflowing, and the separation continues in the succeeding tank; but the last tank is for receiving only, from which the oil is pumped into storage. Two or more of the tanks are equipped with steam heating pipes to maintain a temperature of 165° F. in the mixture.

This process leaves in the bottom of the four tanks a mixture of water, finely divided flesh particles and a little oil.

Foots recovery apparatus

A recently devised machine, the foots machine, which consists of a rotating hexagonal screen, a collecting pan and a small screw press, is used to recover the solids remaining in the sludge.¹² Sludge from the tanks is pumped into the rotating screen, where the solids are retained; a slight inclination of the screen is sufficient to cause the material to collect at the lower end, where it drops into the hopper of the press, directly below the screen. The foots press is identical in construction with the main press but noticeably smaller. Press cake

¹² The screen is of 60-mesh wire, 10 feet long and 3 feet in diameter. The foots press is 4 feet long and has 8 flights.

from the foots press is returned to the conveyor feeding the wet meal disintegrator.

Situated between the screen and the press is a collecting pan which receives the liquor that has passed through the screen; the liquor from the foots press also joins the same discharge. This so-called stick water from the foots machine is generally discarded, but present indications are that further separation of oil and solids from the stick water can be made profitably. One attempt at present is being carried out commercially with every indication of success; it is still however rather experimental and will not be described in this paper.



FIG. 136. The foots machine, showing the drip pan beneath the frame for the screen, and the press directly under the pan. The press hopper may be seen to the right of the photograph. (As is customary the screen is removed during the off season, at which time the photograph was taken.) Photograph by E. L. Macaulay.

Vibrating screens

Vibrating screens have only recently been installed in California plants and so far but few are in use. They may be used for the primary removal of solids from the press liquor or in conjunction with the foots machine. They may also serve to recover solids from the centrifugal or settling tanks waste liquor. In recovering solids in the settling tank system or in conditioning the liquor fed to centrifugal separators, from 60-mesh to 80-mesh is used in the screen; for recovering solids from the centrifugal discharge, where the material to be sized is much smaller, a 150-mesh screen is used. Sizing of the particles is made possible by the rapid vibrations of the screen. The

vibrator shaft runs at 1800 revolutions per minute and imparts a circular motion to the screen with a one-eighth inch throw. Liquor hits the screen from an overhead feed, and because of a slight inclination the solids collect at the bottom of the screen to be returned later to the press. The liquor is collected below in drip pans, whence it enters the centrifuges or is discharged, as the case may be.

Better results are obtained when the material to be screened is first heated to a temperature of 190° F..



FIG. 137. A vibrating screen. The triangular receiving hopper is in the foreground. Attached to the frame of the screen is the motor, and the vibrator shaft leading from it. (The actual sizing screen which fits above the one shown had been removed at the time the photograph was taken.) Photograph by S. Ross Hatton.

Centrifugal process¹³

Many advantages are claimed for the centrifugal method of handling press liquor over the settling tanks system. In actual practice the claims seem to be well substantiated. The application of this method to the fish reduction industry in the East and in Europe and Asia seems to be more general than in California. Its success in our own plants is apparently indicative of a more general application on the Pacific coast. It is claimed that this method greatly reduces the free fatty acid content of the oil, produces oil of a better color and lower moisture content, and reduces the oil and solid content of the stick water.

This process of oil recovery consists essentially of two steps: first, the bulk of the solids is removed from the press liquor; and second,



FIG. 138. The bulk centrifuge. The motor shaft is between the uprights. The skimming nozzle and its adjusting device are attached to the outer shell of the basket. Photograph by S. Ross Hatton.

the oil and water are separated from each other, and some additional solids are recovered. The solids in the first step are removed by a motor-driven suspended solid basket centrifuge, commonly called the bulk centrifuge, developed to meet the need of removing solids so that the liquid components of the discharge could be handled by ordinary mechanical separating methods.

Press liquor enters a feeding tank, then flows into the basket of the bulk centrifuge. As the name indicates, this basket is suspended on a center shaft attached to an overhead motor, and under operating conditions it revolves at a speed of 1200 revolutions per minute, a speed which gives a centrifugal force equal to about 800 times the

¹³ The authors wish to express an indebtedness to Mr. T. J. Griffin for much of the material contained in this section and also for his help in revising this part of the manuscript.

force of gravity. Solids, being the heaviest components of the material, are collected on the side of the basket in the form of a bowl cake, with a moisture content sufficiently low to allow the bowl cake to be returned directly to the moist meal entering the dryer. Along the sides of the basket, projecting about four inches inward, are six vertical vanes that serve to prevent slippage of the liquid, *i.e.*, if the vanes were not present the liquid would have a tendency to rotate at less speed than the basket. After the bowl cake has built up to a sufficient thickness, the basket is braked to a stop and a scraper run between the vanes to remove the cake through the bottom of the basket. Under normal operating conditions, the cake of approximately 375 pounds of 60 per cent solids is removed twice hourly, requiring from seven to eight minutes for each discharge. Some baskets are equipped with five horizontal vanes, which serve the same purpose as the vertical



FIG. 139. Two high speed centrifuges ready to be installed. Photograph by S. Ross Hatton.

vanes. When the vanes are horizontal, the bowl cake is removed by a scraper plow, consisting of a flat scraper of sufficient width to fit between two vanes. The scraper is suspended from a shaft that may be raised or lowered to correspond to the different levels of the vanes. In order to empty the basket, the scraper is placed in position between two vanes while the basket is slowed to 50 revolutions per minute; after a few revolutions the scraper is removed and placed between the next two vanes, and so on until the collected solids are completely discharged.

The accumulation of heavy solids on the basket wall leaves an almost clear liquid in the center of the bowl, which is removed by a surface-skimming collection nozzle to a feed tank and then to a flash heater.

The basket is 40 inches in diameter and 18 inches deep, and has a capacity of 15 tons per hour, or, roughly, 3000 gallons of press liquor. The number of bulk centrifuges employed depends of course on the press capacity.

From the bulk centrifuge the liquid effluent now enters a flash heater, where the temperature of the material is raised to 200° F. by injection under pressure of live steam into the oil as it is passing into the receiving tank for the high speed centrifuges.

The high speed centrifuge is designed to separate two immiscible liquids of different specific gravities and simultaneously to remove any remaining solids. This operation and its accomplishment will be familiar to a great many readers, at least to those who have had experience with the ordinary cream separator. The actual separating parts are contained in a bowl and consist of 30 identical disks or curved plates, placed close together, for the purpose of dividing the liquid into thin layers. Material enters the bowl through a central tubular channel, and under the action of centrifugal force the heavier components (mainly stick water) are flung to the outside of the bowl, while the lighter portions (oil) rise up the center. A continual inflow of material creates sufficient pressure to force the oil and waste water through separate outlets, while some few remaining solids are also discharged in the form of a sludge from the bottom of the bowl during the unloading operation.

A notable feature of the modern high speed centrifuge is the automatic sludge unloading arrangement, which operates at full running speed. By introducing water into a special chamber beneath the bowl proper, hydrostatic pressure is generated in this chamber by the rotation of the bowl. This pressure forces the bowl to slide upwards, uncovering a slot which extends around the bowl, through which the accumulated sludge is forced out. The actual unloading time requires about 10 seconds and is necessary every 20 minutes under usual conditions. This sludge may be returned to the tank feeding the bulk centrifuge and re-run.

Three high speed centrifuges, each of 5 tons capacity, operating at 6400 revolutions per minute and creating a centrifugal force 7000 times the force of gravity, are required to handle the liquid discharge from the bulk centrifuge. From the press to the completion of the centrifugal separation the oil is in process from 5 to 10 minutes.

Some operators retain the foots machine, vibrating screen, or some device to accomplish the equivalent of the work, and substitute high speed centrifuges for settling tanks, thus making the bulk centrifuge unnecessary.

Ordinarily the high speed centrifuges accomplish the last step in handling the press liquor. The oil is run into storage, and the stick water discarded. Some operators, however, before marketing the oil, subject it to additional treatment by a continued purification or by fortification with other oils, generally fish liver oils, to increase the vitamin content. In no event is it necessary to cook sardine oil before storage, as is the case with menhaden oil.

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CALIFORNIA SEA LION CENSUS FOR 1938 ¹

By PAUL BONNOT, G. H. CLARK and S. ROSS HATTON

Bureau of Marine Fisheries

Division of Fish and Game

Two species of sea lions are found along the coast of California. Steller's sea lion (*Eumetopias stelleri*) ranges from Santa Cruz Island northward to Alaska while the California sea lion (*Zalophus californianus*) occurs from the Farallone Islands southward into Mexico.

As a result of periodically recurring interest in these animals and their activities, five surveys of the sea lions occurring on the coast of California have been made during the past ten years by the California Division of Fish and Game. The rookeries and hauling grounds have been located and counts and estimates have been made to determine the numerical strength of the population during the breeding season, at which time the sea lions are concentrated on the rookeries.

Many commercial and sport fishermen maintain that the sea lions destroy vast quantities of fish and do extensive damage to fishing gear. It is seldom that a friendly voice defends these animals. However, in 1937 several individuals and societies protested vigorously because of the activities of a company engaged in killing and canning, for dog and cat food, California sea lions in Mexican waters. The commercial fishermen in the southern part of the State during the period of the operation of the dog and cat food company were unusually vociferous in their claims of sea lion damage and in their insistence that the herds had greatly increased. It was thought possible that there might have been a northward migration of California sea lions to the California coast from Mexican waters in order to escape persecution. The present survey, between June 13th and 26th, 1938, was primarily to determine the validity of this supposition.

The survey was made with the patrol boat *Bluefin* and was conducted in the same manner as were the previous counts, except that three observers, instead of one, covered the coast line, hence the population figures for 1938 represent averages of three individual counts or estimates. It can be seen readily from the appended table that the data for the 1938 season do not vary appreciably from those of the earlier surveys.

Sea lions are not such slaves to habit as are their cousins, the fur seals, who return year after year to the same rookery where they were born. The sea lions change their rookery sites from time to time for reasons which are sometimes obscure. Rookeries which may have flourished for years on the same beach or rock will be found abandoned whereas a rookery will suddenly appear where no sea lions have ever been observed. It is necessary, therefore, in making a survey to touch not only at all the known rookeries and hauling grounds but also

¹ Submitted for publication, September, 1938.

to visit many likely places on a chance that a new rookery may have appeared. Two such changes were noted during the present season. The Point Arena rookery was abandoned by the Stellers usually found there, while a small group of Californias was found at Cochie Point on Santa Cruz Island, adding a new rookery to the list. Sea lions were not found at Cochie Point during any of the previous surveys but old records report them as occurring at this point.

During the last few years the Chinese market for sea lion trimmings has practically disappeared, and as the present California law gives the sea lions complete protection no evidence was seen of any systematic hunting at any of the offshore rookeries where the trimming hunters formerly worked. Because of these conditions there has been a comparatively large increase in the number of adult bulls and several localities which were formerly merely hauling grounds have now become rookeries.

The absence of persecution may also account for the appearance of two species of marine mammals not observed during the previous surveys. Three Guadalupe fur seal (*Arctocephalus townsendi*) bulls were seen at one place, and four yearling sea elephants (*Mirounga angustirostris*) were noted at another. Both these species were once abundant on the California coast and the present suspension of human predatory activities on the offshore areas may afford them a chance to again become part of the natural fauna.

A great deal of misinformation concerning sea lions is actively promulgated by sport and commercial fishermen and by casual observers. It is claimed that the animals destroy vast quantities of fish and damage a great deal of fishing gear. While it is conceded that sea lions occasionally destroy or damage fishing gear and that they do eat fish, sometimes commercially valuable ones, no evidence has ever been produced which shows that they do any extensive damage in either respect. Evidence on these points, obtained by trained men, tends to show that the animals may sometimes be of benefit to commercially valuable species of fish by destroying predatory fish.

Marine commercial and sport fishing along the California coast has expanded very rapidly during the last twenty years. There has been a great increase in fishing equipment and in fishing effort. So enormous has been the tonnage of fish landed yearly that several species are showing signs of depletion. It is possible that with this great increase in human fishing effort and the consequent removal of great quantities of fish that the fishing competition of the sea lions, although always present, has simply become more noticeable, as the animals are forced to extend their efforts to maintain themselves in the face of a diminishing food supply. It is human nature to shift responsibility. The growing scarcity of some species of fishes and consequently the greater effort required to take them, makes it expedient to find some destructive agency unrelated to human activity.

During the last ten years the sea lion population has remained at about the same numerical level. Although the trimming hunters have stopped killing the adult bulls and the State law protects the animals, still a good many are killed annually by sportsmen and fishermen. The environment in which the sea lions live is not conducive to a long existence. A sick or crippled sea lion is a rarity and old

specimens are scarce; the supposition being that any physical weakness marks the individual for prompt elimination. Although this is true for most animals living in a natural environment, it seems to be unusually so in the case of marine mammals. The breeding cows produce a single pup each year and while the number of pups on any rookery may be fairly large at the termination of the pupping time, about 25 per cent are eliminated on the rookery by accidents and drowning. Not more than 50 per cent of any year's crop of pups reaches the age of one year, and as the death rate among the adults is comparatively high, the present birth rate seems to about balance the death rate.

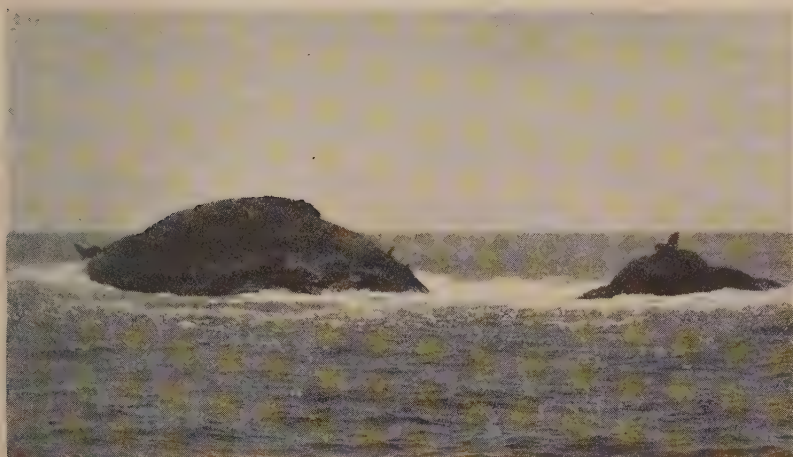


FIG. 140. Sea lions on Turtle Rock, near Trinidad Head, California. Photograph by G. H. Clark, June, 1938.

Most of the protests dealing with the destructive activities of sea lions include the complainant's idea of the numerical strength of the population, usually some figure between 50,000 and 100,000 or more. These statements represent a few casual observations at one or two points along the coast by untrained observers. The figures in the tables appended to this report, representing counts and estimates made during five surveys, over a period of ten years, and including the whole California coast, may be taken as a close approximation of the actual numbers found in State waters.

The California sea lion population is not increasing. The depredations of the animals are nowhere as extensive as is claimed, and for the present there seems to be no reason to reduce their numbers.

NUMERICAL COMPARISON OF SEA LION ROOKERIES AND HAULING GROUNDS FOR YEARS IN WHICH CENSUS WAS TAKEN

Rookery or hauling ground	Steller					California				
	1927	1928	1930	1936	1938	1927	1928	1930	1936	1938
St. George Reef	1,500	611	700	652	325					
Turtle Rocks	200	200		100	93					
Cape Mendocino	700	700	900	700	500					
Point Arena	300	206	300	142						
Point Reyes				45	6					
Farallon Islands	700	540	900	500	357	6		28	25	90
Purissima	150	42		4	2					
Ano Nuevo	1,500	1,500	2,500	1,000	2,000				206	
Bird Rock				25	53				250	
Cypress Point					1					15
Point Lobos		200	49	60	120		70	160	3	1
Cape San Martin		50							20	
Piedras Blancas	212	100	34	6	73	86	1	23	35	21
Lion Rock	86			60	243	21	6		20	10
Pecho Rock	135	95	300	70	3	7	75			3
Point Sal				75	35	10			150	25
Point Arguello				50	2		10		20	
San Miguel Island	595	592	620	1,359	1,992	149	429	205	520	714
Sandy Point	49	38	12	52	20					
Frazer Point	2		40		15	63	88	95		25
Gull Island	18	10	5			150	105	68	200	25
Cochie Point					1					75
Anacapa Island						34	27	11	11	10
Santa Barbara Island						125	327	8	600	500
Castle Rock						29	23	7	35	15
Seal Harbor	1					235	228	340	400	475
Catalina Island										15
Totals	6,148	4,884	6,360	4,900	5,841	915	1,389	945	2,501	2,020

POPULATION OF SEA LION ROOKERIES AND HAULING GROUNDS IN CALIFORNIA - 1938

Location	Steller			California		
	Bulls	Cows	Totals	Bulls	Cows	Totals
St. George Reef	32	293	325			
Turtle Rocks	9	84	93			
Cape Mendocino	150	350	500			
Point Reyes	1	5	6			
Farallone Islands	97	260	357	40	50	90
Purissima	1	1	2			
Ano Nuevo	500	1,500	2,000			
Bird Rock	4	49	53	1		1
Cypress Point	1		1	15		15
Point Lobos	15	105	120	1		1
Piedras Blancas	5	68	73	5	16	21
Lion Rock	28	215	243	10		10
Pecho Rock	3		3	3		3
Point Sal	5	30	35	5	20	25
Point Arguello	2		2			
San Miguel Island	526	1,466	1,992	254	460	714
Sandy Point	3	17	20			
Frazer Point	2	13	15	4	21	25
Gull Island				5	20	25
Cochie Point	1		1	12	63	75
Anacapa Island					10	10
Santa Barbara Island				100	400	500
Castle Rock				3	12	15
Seal Harbor				100	375	475
Catalina Island				8	7	15
Totals	1,385	4,456	5,841	566	1,454	2,020

DETAIL OF ROOKERIES ON SAN MIGUEL ISLAND, 1938

Rookery	Steller			California		
	Bulls	Cows	Total	Bulls	Cows	Total
Richardson Rock.....	50	400	450			
Wilson Rock.....	3	17	20			
Flea Island.....	100	500	600	50	200	250
Offshore Rock.....	5	15	20			
Isthmus Rock.....	8	14	22	4	10	14
Lion Rock.....	10	20	30			
Point Bennett.....	350	500	850	200	250	450
Totals.....	526	1,466	1,992	254	460	714

WHALE SHARKS STRUCK BY FISHING BOATS OFF THE COAST OF LOWER CALIFORNIA ¹

By E. W. GUDGER

*Honorary Associate in Ichthyology
American Museum of Natural History*

The Hydrographic Office of the United States Navy has for a number of years been collecting from the reports of ships' officers notes on the occurrence of whale sharks in various parts of the world and forwarding these to me. In this way there have come into my hands invaluable data on the occurrence of *Rhincodon typus* in various waters and on its unusual capture by being impaled on the bows of vessels. Latest of these courtesies is the transmission by Captain L. R. Leahy, Hydrographer, of a brief account of a whale shark struck (but not impaled) by a fishing vessel off the coast of Lower California. This, which also gives interesting data on the habits of *Rhineodon*, is from Mr. P. Nielsen of Nestor, California, who has been good enough to give me some further details from his private log, made while acting as navigator of the vessel.

Mr. Nielsen writes that he has seen whale sharks as far north on the outer coast of Lower California as Hipolito Point in about 27° north latitude. Farther south they are more common. The tuna fishermen all know them; since they are often found associated with schools of tuna. When a whale shark is seen close at hand, the fishermen often throw bait overboard to bring the tuna to the surface. *Rhineodon* will often eat this bait of sardines and anchovies. These great sharks are quite abundant around Cape San Lucas and are so unafraid that they circle around the fishing boats and almost come within reach. This agrees with Dr. William Beebe's account of his experiences in this region two years ago.

Mr. Nielsen was serving as navigator of the tuna boat whose collision with a whale shark is now to be noted. He did not see the fish, but since the fishermen all know the whale shark as well as they do the tuna, there can be no doubt of the accuracy of their observations. Mr. Nielsen unreservedly vouches for them. He assures me that such collisions are by no means uncommon to vessels of the tuna fleet in these waters, and that if one could talk with the tuna fishermen at San Diego, California, one could collect many such accounts. Here is the brief story of the incident which happened to his vessel, and for which he has notes in his log.

On September 19, 1932, the M. S. *Funchal* struck a whale shark about 2.00 P.M., while in latitude 25° 30' N. and longitude 113° 20' W. (approximately). Mr. Nielsen was below but went immediately on deck since the impact made him fear that the vessel had struck a

¹ Submitted for publication, May, 1938.

rock. One of the crew saw the fish, declared that it was a whale shark, and that as it swam away he saw a large smear of red copper paint across its back.

That the shark was bumped rather than rammed is due to the fact that while the *Funchal* is a wooden vessel, 106 feet long and draws about 12 feet aft, the stem is cut away forward so that she draws only about 5 feet there.² This conformation of the stem brought it about that the blow was a glancing one instead of the ramming blow when the stem is vertical. Since the whale shark has a thick skin (about 4 inches thick in a 30- to 40-foot specimen), such a glancing blow from a wooden vessel might arouse and annoy the shark, but it could do little or no hurt.

Illustrative of the fact that these bumpings are not uncommon in his experience, Mr. Nielsen communicates this further incident. In 1933, he was on the *Santa Margarita* of about the same size, build and draft as the *Funchal*. One night, when about 25 miles southeast of Cape San Lucas, in a locality abounding in whale sharks, he was aroused and brought on deck by a shock which brought the vessel to a dead stop and made him think that she had struck an uncharted rock. However, after a moment, the vessel continued on her course. Now since it was not a rock, nothing but a whale shark (or an uncommonly found whale) would have brought the vessel to a standstill, and, although the fish was not seen, everybody accepted the whale shark explanation and thought no more of the matter.

Since this article was submitted for publication, Captain G. S. Bryan, Hydrographer, has kindly communicated a report of a whale shark which had a violent encounter with the American schooner-yacht *Navigator* of San Pedro. Captain Fred K. Klebingat, master of the *Navigator*, writes that on May 8, 1938, in latitude 24° 25' N. and 110° 13' W., near Cape San Lucas:

"The vessel was struck on the starboard side by an immense shark. The wheel was wrenched out of the hands of the man at the wheel. The tail of the fish rose eight feet above the rail of the ship and about 14 feet above the waterline. The engine was stopped [since] the fish struck the propeller. The fish was distinctly seen when it went astern, was of a mottled color and was at least 30 to 35 feet long. After going into drydock, it was found that considerable damage had been done to the hull and rudder of the ship. Two more sharks [of the same kind] were seen in the same locality the next day."

Here again is more first hand evidence that this largest of living sharks is harmless, sluggish and unafraid. Its entire fearlessness and its desire to eat the bait thrown out by the fishing boats as "chum" for tuna, lead it to "hang around" these boats, and its sluggishness not infrequently leads to its getting "bumped" by them. In the cases cited, the fish may have swum across the bow of the boat or may have lain inert in her course. I have a record of a *Rhineodon* which swam so leisurely across the path of a vessel that it was missed by a few feet only. These habits tie up with all the evidence that I have gotten in 25 years' study of the behavior of *Rhineodon* all over the oceans.

² The *Funchal* was destroyed by fire, March 13, 1938.

NOTES

NOTES ON THE RIBBON-FISH, *TRACHYPTERUS REX-SALMONORUM*

During the summer of 1938, six specimens of the ribbon-fish, *Trachypterus rex-salmonorum* Jordan and Gilbert, have been brought to the attention of staff members of the California State Fisheries Laboratory. This "king-of-the-salmon" is one of the most unusual of the fishes inhabiting the eastern Pacific and it and the several other species known from various parts of the world form a group about which we have little information. Extremely delicate, such specimens as have been found are usually damaged to some extent, and a well-preserved specimen is a rarity. That these fishes undergo a pronounced metamorphosis is known (Hubbs, Mich. Acad. Sci., Pap., 1925, 5:469), but as to other particulars of their life-history and habits we know very little. They are commonly supposed to be rare inhabitants of great depths; that they are probably neither is indicated in an inconspicuous note written by W. F. Thompson in 1919 [Calif. Fish and Game, 1919, 5 (2):95], in which we read: "[*Trachypterus*] is supposedly very rare. But in the explorations of the *Albacore* numerous young have been taken." A few of the *Albacore* hauls were made at depths of 50 to 100 fathoms, but for the most part they were made much nearer the surface.

Further indication that these fish are not uncommon is accorded by the discovery of five specimens in the stomach of a wolf-fish, *Alepi-saurus aesculapius*, taken at Redondo Beach, Santa Monica Bay, California, on June 13, 1938. They could be readily identified although they were partially digested. It was impossible to obtain exact measurements on these specimens, but standard lengths ranged from approximately 10 to 20 cm. The stomachs of all five were intact. Mr. Howard McCully examined their contents and identified the following material:

Specimen A: Large numbers of copepods, seemingly of one species.

B: Many annelid worms; a few copepods representing at least two species, one the same as found in "A."

C: Two copepods, the same species as in "A."

D: Three loricate fish larvae.

E: Empty.

The sixth specimen to come to our attention was given to the Laboratory by Mr. Harry Evans of San Pedro. The manner in which he caught the fish is most unusual. While working on his boat which was tied at the foot of Twenty-second Street, San Pedro, well inside of Los Angeles Harbor, he noticed the fish swimming by. Recognizing it as something out of the ordinary, he landed it in a dip net. This was on March 20, 1938. A remarkably fine specimen, about 19 cm.

standard length, it has been deposited in the Stanford University collection. Before preservation it was an extremely beautiful fish. All of its fins were a bright red while its silvery body was accentuated by a series of four dark blotches situated dorsally along the sides. The front of the head was darkened as well. Mr. Evans reported that the first dorsal ray had terminated in a red knob, but this was missing when we received the specimen. Except for the lack of ventral blotches, the fish answered well to the description given by Jordan and Evermann [Fishes of North and Middle America, 1898 (3):2599].—*Phil M. Roedel, California State Fisheries Laboratory, August, 1938.*

RECORD-SIZE MACKEREL IN SANTA MONICA BAY

It is very probable that fish attaining record sizes are often taken but as a rule are not brought to the attention of ichthyologists who are naturally interested in such occurrences. However, there are occasions when unusual specimens are turned over to the Division of Fish and Game. A Pacific mackerel (*Pneumatophorus diego*), larger than ever recorded before at the California State Fisheries Laboratory, was caught on hook and line by James Putters, a commercial fisherman, on June 8, 1938, in Santa Monica Bay. This fish measured 24.8 inches and weighed 6.36 pounds, which is slightly larger than the mackerel reported by J. B. Phillips as landed at Monterey in August, 1937 (Calif. Fish and Game, vol. 23, p. 337). The Monterey specimen, of record size at that time, measured 24.5 inches and weighed 6 pounds. A mackerel of half that weight and 20 inches in length is considered large.

The Santa Monica fish was a female with running eggs and its measurements (prior to preservation) were: total length, 630 mm.; length of head, 137 mm.; distance from tip of snout to insertion of dorsal fin, 182 mm.; tip of snout to anus, 357 mm.; weight, 2886 grams.—*Phil M. Roedel, California State Fisheries Laboratory, August, 1938.*

REVIEWS

The High Seas Tuna Fishery of California

By H. C. Godsil. California Division of Fish and Game. Fish Bulletin, no. 51, 41 pp., 20 figs., 1938.

The author, a member of the staff of the California State Fisheries Laboratory, has had considerable experience in tuna fishing, having made frequent trips into southern seas with vessels fishing commercially for tuna. In addition to this intimate knowledge of the subject, Mr. Godsil has written in a direct simple style that results in a text that is packed with information but arrestingly interesting and easily read. An account of the tuna fishery has long been needed and this bulletin admirably describes the fishing methods, the gear used and the fleet of boats engaged in this spectacular fishery off the coasts of Mexico and Central and South America.

This account of the tuna fishery concerns itself chiefly with the operations of the fleet of live bait boats which catch most of the tuna landed in California for canning. It is this fleet of large high sea ships, numbering about 50 vessels, that has caught about three-fourths of the tuna (yellowfin and skipjack) delivered to our canneries. There is a brief account of the small boat fleet of about 25 vessels that use live bait for catching yellowfin tuna and skipjack when these fish are within their cruising radius, but at other seasons of the year they necessarily must turn to the catching of yellowtail and bonito. This bulletin does not discuss the local small scale tuna fishing as carried on by purse seine boats during a part of the season.

The high seas fleet of larger boats includes those vessels, 90 to 130 feet or over in length. It is these vessels, with crews of 12 to 20 men, that make the long trips of six to eight weeks down to and occasionally beyond the Equator and return to Southern California canneries with loads of 150 to 350 tons of tuna, after cruises of 6000 to 8000 miles. The insulated fish hold is equipped with refrigeration machinery for holding low temperatures where the fish are packed in chipped ice or held in chilled brine. Live bait is carried on the stern deck in huge tanks with circulating sea water.

The report covers the complete fishing operation from provisioning the ship for the long voyage, obtaining bait and landing tuna on deck, to icing down the catch and delivery to the canning plant. This account is well illustrated, many of the action photographs having been taken by the author. In addition there are two maps of the fishing areas covered and a graph of the trend of annual catches of yellowfin and skipjack. A brief list of references is included.—*W. L. Scofield, California State Fisheries Laboratory.*

Improvement of Lakes for Fishing—A Method of Fish Management

By Carl L. Hubbs and R. W. Eschmeyer. Michigan Department of Conservation, Institute for Fisheries Research, University of Michigan. Bulletin, No. 2, 233 pp., 74 figs., annotated bibliography, index. Lansing, Mich. \$1.25.

Michigan has long been noted as one of the leaders in the improvement of fishing as a result of practical fisheries research. The appearance in 1932 of "Methods for the Improvement of Michigan Trout Streams," by Carl L. Hubbs, John R. Greeley and Clarence M. Tarzwell (Institute for Fisheries Research. Bulletin, no. 1, 54 pp.) was instrumental in prompting active fisheries management work in many other states which were quick to follow Michigan's lead. This second bulletin, "The Improvement of Lakes for Fishing," is a sequel to the earlier handbook, and is the result of many years of trying to evolve ways to improve lake fishing. The bulletin lists all of the devices and expedients that can possibly be used to "shorten the time between bites." As a guide to the improvement of lakes, the bulletin will prove invaluable, as it is the first comprehensive publication on this subject. The authors are outstanding fish management experts and they have had the assistance of a great many other able scientists so it is no wonder the bulletin has turned out so well.

The first part of the publication lists the necessity for improving conditions in lakes to provide better fishing, and how this can best be accomplished. Following are detailed accounts of how to provide the best conditions, together with discussions of the desirability of each device. Twenty methods of improving conditions for lake fishes are discussed: improving the shelter (including details of shelter construction), managing the plant growths, bettering the spawning conditions, regulating the abundance of fish, altering the depth, regulating the fluctuations of water level, increasing the natural food, decreasing algal nuisances, retarding destructive wave action, preventing erosion and silting, controlling pollution, aerating lakes and removing causes of oxygen deficiency, modifying the temperature, managing fish movements, handling populations with stunted growth, managing competitors, removing the excess of coarse fish, controlling predators, treating and preventing diseases, and preventing depletion from overfishing.

Accompanying the text are some very fine descriptive photographs and drawings, many of which show the construction of improvement devices in such detail that they would serve as models.

A well-illustrated chapter on the very important subject of the improvement of artificial lakes has been contributed by Walter W. Aitken and J. Clark Salyer II. This section describes the work done by the Iowa State Conservation Commission in creating artificial lakes to provide fishing. Man-made lakes lend themselves readily to improvement projects because shelters, spawning beds, rip-rapping, etc., can be installed before the lake fills with water.

The words of the authors themselves best tell the place of lake improvement in fish management—its possibilities, practicability and limitations:

"At least for the near future, lake improvement can not be foreseen as a substitute for the long-recognized practices in fish management (restrictive and protective legislation, law enforcement, and

the introduction of fish and the stocking of artificially propagated and reared fish). Methods of lake improvement would need to be enormously perfected, before this new practice, if ever, could be expected to replace the older means of maintaining the fish supply.

Moreover, other new methods of fish management are being developed, and the older methods are being modernized and made more effective.

As announced on the title page, 'Improvement of Lakes for Fishing' will continue to be 'A Method of Fish Management.' The text has been restricted largely to a consideration of the physical, chemical and biological factors responsible for a good fish crop, and to suggestions for the design, construction and installation of devices by which these environmental factors can be controlled and altered so as to maintain or increase the fish crops. Despite this purposeful limitation of the subject matter, the treatment has required frequent reminders that other methods have been and will continue to be of large importance in the development of the theory and practice of fish management. Indications are also given, with perhaps inadequate accent, to the importance of the economic and social phases, which no doubt will frequently prove to be the dominant factors in determining the extent and kind of fish management to be practiced. The very sketchy treatment or bare mention of these other methods and relations is not the result of an assumption that they are unimportant. These other phases now deserve or within a few years will become fit subjects for specific bulletins and texts, which will take their place among many similar treatises in the field of game and still other aspects of wildlife management.

Theory and practice in fish management, as in the management of any wildlife or domesticated crops, involve the deliberate and skillful control of populations, not only of the crop species being cultivated or favored, but also of the other species of animals and plants which have or might have an important effect on the desired yields. Usually the populations of several other species will need be controlled in order to increase the production of the species to be favored, because the interrelationships between competition, predation, disease and the environment are ordinarily complex. Among fishes, some species often bear the same relation to the game fishes that weeds bear to the cultivated plant crops. In managing fish and other animal crops, control of the population (abundance) of certain plant species is also apt to be of particular importance, because in any natural association all the animals are permanently dependent on plants as the basic source of food material, and because the plants also aid in providing facilities for shelter and reproduction.

In the culture of any crop, the weed and crop species are controlled only in part by modification of the environment—as by plowing, cultivating, fertilizing, cutting fire lanes, growing cover along fence rows, installing brush shelters, improving the facilities for natural reproduction, etc. The planting, thinning, harvesting and marketing of the crops, or similar procedures, are often of greater moment in making the crop pay. Whether under given conditions, the most effective and economical results in the control of wild populations can be obtained by the indirect methods of environmental control (as by

lake improvement in fish management) or by the more direct procedures such as stocking and regulating the take, or (more likely) by a combination of these methods, can only be determined by repeated trials and checks.

"In general the technical phase of fish management is chiefly concerned with devising and testing new and better ways to control the production of desired species; and in devising new and better tools and procedures for measuring with precision the results and practicability of each operation or procedure, old or new.

"In controlling the production of desired fish (as of other crops), it is of vital importance to determine the populations of each species, at different ages, and from season to season and year to year. Almost nothing has been known of the standing crop or of the annual take of fish in inland lakes, or of the carrying capacity of the lakes. Little actual data has been obtained on the great natural destruction of fish that takes place at different stages of the life cycle, from eggs and fry through yearlings and half-grown to breeding adults. With such ignorance of natural fish populations, much current fish management practice is equivalent to planting trees without consideration of the number and kind and size of trees already present, or of the amount of timber annually cut and removed. Or it compares with putting a certain number of calves into a pasture without taking into account the number of cattle already there, the carrying capacity of the field or the number of animals annually marketed from the pasture. It is like planting seed without considering the standing crop or the harvest.

"Slowly but surely, however, it is being shown through creel census records what kinds, numbers and sizes of fish are being removed from different types of waters. Even more slowly, investigators are beginning to show through population studies what is actually available for the angler. They are finding that in some waters of southern Michigan only a very small percentage of the available adult fish are removed each year by the fishermen, that fishing is poor in some lakes, especially in the north, because there is too little food for the number of fish present, and because these fish, though typically very abundant, do not often reach legal size.

"Technical work in agriculture has indicated that many of the old methods were futile or inadequate and has suggested new and better ways of obtaining the desired crops in larger quantities. As compared with agriculture, the technical phase of fish management has hardly been started, but already it is suggesting that by no means all stocking has been effective, that some laws have at times proved detrimental instead of helpful, and that the unintelligent or too little understood application of lake 'improvements' may be ineffectual or even injurious to fishing.

"Quite obviously, all wildlife managers should become familiar with the pertinent aspects of the technics of population control and the methods of checking which have become established in the older lines of crop production. The control of plant and animal populations since prehistoric times has resulted in modern agriculture. Control technics have now been elaborately developed and tested for many of the preferred farm, garden, range and forest species. Agronomy, horticulture and forestry are consequently much farther advanced than

are the corresponding technics for growing wildlife crops, such as game, fur and fish. Wildlife workers should thus profit, on occasion, by avoidance as well as by duplication.

"The methods of the agriculturist and the forester should in general prove applicable in wildlife management and investigation. The difference between the culture of domesticated and wild crops seems to be largely one of degree rather than kind. The domestic crops are of course much more intensively cultured, as would be shown by computing the typical, annual per-acre investments in dollars and in labor, for the several crop species—farm, ranch, orchard, forest, game and fish. But there is the identical objective: frequent, generous and dependable yields of the desired species, year after year from the same units of land or water; obtainable at practicable costs, and readily available for human use or enjoyment."—*Richard S. Croker, Editor, California Fish and Game.*

REPORTS

DEPARTMENT OF NATURAL RESOURCES, DIVISION OF FISH AND GAME, STATEMENT OF REVENUE

For the Period July 1, 1937, to June 30, 1938, of the Eighty-ninth Fiscal Year

Revenue for the Fish and Game Preservation Fund, Current Year

License sales:	Detail	Total
Hunting, 1936-1937.....	\$20,000 50	
Hunting, 1937-1938.....	418,934 53	
Hunting, 1938-1939.....	142 00	
Angling, 1937.....	391,848 35	
Angling, 1938.....	237,733 19	
Trapping, 1937-1938.....	2,574 00	
Trapping, 1938-1939.....	3 00	
Deer tags, 1937.....	124,109 68	
Deer tags, 1938.....	80 00	
Market fisherman, 1937-1938.....	45,020 00	
Market fisherman, 1938-1939.....	25,380 00	
Game breeders, 1937.....	117 50	
Game breeders, 1938.....	982 50	
Fish breeders, 1937.....	40 00	
Fish breeders, 1938.....	355 00	
Fish importers, 1937.....	20 00	
Fish importers, 1938.....	95 00	
Fish packers and wholesale shellfish dealers, 1937-1938.....	1,070 00	
Fish packers and wholesale shellfish dealers, 1938-1939.....	30 00	
Kelp license, 1937.....	20 00	
Kelp license, 1938.....	20 00	
Commercial hunting club, 1937-1938.....	900 00	
Commercial hunting club operator, 1937-1938.....	280 00	
Fishing party boat permit, 1937.....	186 00	
Fishing party boat permit, 1938.....	377 00	
Fish tags.....	3,815 97	
Game tags.....	243 41	
Total license revenue.....		\$1,274,377 63
Other revenue:		
Fish packers tax.....	\$237,688 40	
Salmon packers tax.....	37,284 65	
Kelp tax.....	253 45	
Lease of kelp beds.....	1,666 36	
Court fines.....	42,212 25	
Interest on bank balances.....	712 73	
Publication sales.....	15 01	
Other miscellaneous sales.....	5,285 45	
Total other revenue.....		\$325,118 30
Total revenue Fish and Game Preservation Fund.....		<u>\$1,599,495 93</u>

STATEMENT OF EXPENDITURES

For the Period July 1, 1937, to June 30, 1938, of the Eighty-ninth Fiscal Year

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
OPERATING EXPENDITURES, EIGHTY-NINTH FISCAL YEAR					
Administration:					
Accident and death claims.....			\$2,255 29		\$2,255 29
Cashier.....	\$1,200 00				1,200 00
Executive.....	5,000 00	\$233 08	3,352 10	\$919 13	9,504 31
Exhibits.....			1,200 00		1,200 00
General office.....	7,523 38	6,399 93	19,748 61	521 21	34,193 13
Legal.....			6,894 17		6,894 17
Library.....	1,800 00	43 23	143 15	696 69	2,683 07
Property inspection.....	741 33	35 27	137 29	818 44	1,732 33
Pro rata department administration.....	10,000 00		6,000 00		16,000 00
Pro rata General Fund expense.....			9,990 89		9,990 89
Publicity.....			2,035 88		2,035 88
Total Administration.....	\$26,264 71	\$6,711 51	\$51,757 38	\$2,955 47	\$87,689 07
Patrol and Law Enforcement:					
Cannery inspection.....	\$17,403 27	\$1,009 04	\$2,740 14	\$266 48	\$21,418 93
Executive.....	14,220 00	874 22	2,634 29	680 81	18,409 32
General office.....	5,947 80	940 25	1,947 08	1,031 32	9,866 45
Junior patrol.....	2,626 02	330 04	677 64		3,633 70
Land patrol.....	191,731 55	37,471 22	64,147 88	35,203 03	328,553 68
Marine patrol.....	52,800 61	20,210 59	33,517 21	17,786 67	124,315 08
Pollution patrol.....	7,047 52	1,917 47	4,122 47	738 10	13,825 56
Total, Patrol and Law Enforcement.....	\$291,776 77	\$62,752 83	\$109,786 71	\$55,706 41	\$520,022 72
Marine Fisheries:					
Executive.....	\$7,320 00	\$185 85	\$503 21	\$791 69	\$8,800 75
Field supervision.....	3,200 00	353 72	1,894 81		5,448 53
Fish cannery auditing.....			2,697 46		2,697 46
General office.....	8,555 59	142 30	924 85	297 54	9,920 28
Research and statistics.....	40,512 68	5,870 99	11,275 58	2,834 75	60,494 00
Total Marine Fisheries.....	\$59,588 27	\$6,552 86	\$17,295 91	\$3,923 98	\$87,361 02
Fish Conservation:					
Cooperative Research, Stanford University.....	\$3,869 67	\$289 43	\$804 04	\$696 82	\$5,659 96
Executive.....	6,460 00	235 61	602 22	1,026 58	8,324 41
Field supervision.....	10,059 15	1,307 04	3,788 47	3,123 86	18,278 52
Fish planting.....	2,683 87	1,418 54	1,970 42	4,334 24	10,407 07
Fish rescue.....	5,407 85	561 22	1,507 10	2,179 29	9,655 46
General office.....	4,756 40	1,003 86	55 84	452 27	6,268 37
Pollution inspection.....	3,120 00	390 87	763 87	38 56	4,313 30
Research.....	2,142 10	404 47	1,004 08	428 46	3,979 11
Statistical.....	2,280 00	105 54	1,050 50	109 09	3,545 13
Alpine.....	1,313 04	729 68	304 26	550 65	2,897 63
Basin Creek.....	4,690 42	2,532 17	440 69	568 04	8,231 32
Bear Lake Egg Collecting Station.....	433 87	105 47	29 80		569 14
Beaver Creek Egg Collecting Station.....	250 00		75 00		325 00
Beaver Creek.....	148 55	46 90	8 58		204 03
Big Creek.....	3,331 67	2,600 55	326 80	557 36	6,816 38
Blackwood.....	302 81	218 39	1 00		522 20
Blue Lakes Egg Collecting Station.....	590 00	7 08	16 00	105 55	718 63
Bogus Creek Egg Collecting Station.....	407 09	79 94	177 10		664 13
Brookdale.....	3,285 32	1,846 21	438 10	19 78	5,589 41
Burney Creek Hatchery.....	5,500 09	3,369 62	885 77	611 62	10,367 10
Carmen Lake Egg Collecting Station.....	312 00	2 24	10 43		324 67
Central Valleys.....	3,565 14	1,544 46	1,913 70	2,202 68	9,225 98
Cold Creek.....	2,492 27	1,807 59	617 71	579 48	5,497 05
Cottonwood Lakes Egg Collecting Station.....	263 04	43 05	75 23		381 32
Deep Creek Egg Collecting Station.....	200 00				200 00
Fall Creek Egg Collecting Station.....		29 21	85 00		114 21
Fall Creek.....	6,178 55	5,002 96	256 99	6 06	11,444 56
Feather River.....	4,048 21	2,063 92	500 73	247 05	6,859 91
Fern Creek.....	1,667 89	373 61	62 97		2,104 47
Fishing Creek Experiment Station.....		22 25	155 31		535 62
Forest Home.....	10,754 02	9,385 21	3,049 02	293 39	23,481 64
Fort Seward.....	4,294 71	1,210 22	156 55	708 72	6,370 20
Hat Creek Egg Collecting Station.....	130 00	113 98			243 98
Hornbrook Egg Collecting Station.....	243 84	58 63	112 97	20 77	436 21
Hot Creek Hatchery.....	2,928 56	2,455 29	194 10	14 32	5,592 27

STATEMENT OF EXPENDITURES—Continued

For the Period July 1, 1937, to June 30, 1938, of the Eighty-ninth Fiscal Year

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Fish Conservation—Continued					
Huntington Lake	\$731 99	\$594 20	\$256 76	\$30 18	\$1,613 13
June Lake Egg Collecting Station			3 86		3 96
Kaweah	4,533 23	2,015 94	1,175 08	150 32	7,924 57
Kings River Hatchery	4,257 61	1,327 01	1,336 25	47 87	6,968 74
Klamathon Egg Collecting Station	1,412 91	121 48	321 76	12 21	1,868 36
Kosk Creek Egg Collecting Station		8 44			8 44
Lake Almanor	5,989 13	2,077 00	1,007 02	167 22	9,240 37
Lake Eleanor Egg Collecting Station		18 94			18 94
Little Walker Lake Egg Collecting Station	259 03				259 03
Madera	1,170 00	697 22	326 41	11 02	2,204 65
Marlette Lake Egg Collecting Station	713 17	4 79	56 90		774 86
Mt. Shasta Experiment Hatchery	1,061 29	619 29	33 59		1,714 17
Mount Shasta	28,990 38	17,345 83	2,915 92	235 65	49,487 78
Mount Tallac	1,705 65	1,509 42	100 52		3,315 59
Mount Whitney	11,012 85	4,474 64	2,329 00	882 21	18,698 70
Mud Creek Egg Collecting Station	259 49	17 97	3 00	4 50	284 96
Pasadena Reservoir Egg Collecting Station	325 00	4 81	17 25		347 06
Prairie Creek	5,528 15	1,659 84	557 18	640 09	8,385 26
Rush Creek Egg Collecting Station	511 21	49 81			561 02
San Lorenzo Egg Collecting Station	8 00	128 72	1 00		137 72
Scott Creek	1,500 00	140 40	148 25		1,788 65
Shackleford Creek Egg Collecting Station	456 00	36 55	70 00		562 55
Shasta River Experiment Station	152 00	94 74	184 20		430 94
Shasta River Egg Collecting Station	853 54	150 33	49 23	6 64	1,059 74
Snow Mountain Egg Collecting Station	2,305 61	257 91	223 02	19 68	2,806 22
Tahoe	5,730 35	1,959 63	677 48	895 66	9,263 12
Taylor Creek Egg Collecting Station					
Upper Truckee Egg Collecting Station	254 84	48 34			303 18
Waddell Creek Station	831 94	31 24	53 09	21 95	938 22
Warner Creek Station	402 53	54 35	2 40		459 28
Yosemite	3,926 25	1,388 35	313 47	155 83	5,783 90
Yuba River	3,176 64	1,252 10	318 02	3 12	4,749 88
Total Fish Conservation	\$186,576 98	\$79,454 50	\$33,921 11	\$22,158 79	\$322,111 38
Hydraulics:					
Engineering	\$4,911 43	\$652 56	\$1,965 65	\$1,571 77	\$9,101 41
Executive	4,140 00	348 52	857 49	623 41	5,969 42
Fish screens	3,449 16	3,145 28	130 28	3,684 25	10,408 97
General office	1,920 00	93 43	158 86	201 16	2,373 45
Total Hydraulics	\$14,420 59	\$4,239 79	\$3,112 28	\$6,080 59	\$27,853 25
Game Conservation:					
Elk refuge	\$2,176 32	\$407 45	\$539 33	\$180 12	\$3,303 22
Executive	12,122 50	979 54	2,334 68	578 03	16,014 75
Field				17 06	17 06
Game bird distribution	800 00	3,166 56	1,114 27	734 65	5,815 48
Game bird trapping		56 95			56 95
General office	4,278 89	152 31	28 45	103 06	4,562 71
Grey Lodge refuge	3,880 00	1,547 34	1,994 19	1,155 36	8,576 89
Imperial refuge	1,895 16	367 46	86 13	492 26	2,841 01
Los Banos refuge	3,111 10	585 25	632 50	633 39	4,962 24
Los Serranos game farm	14,732 39	6,644 53	2,825 56	2,439 73	26,642 21
Predatory animal control	31,771 73	5,018 98	14,332 33	2,472 05	53,595 09
Research	496 43	74 22	295 57	718 05	1,584 27
Statistics	1,412 74	57 97	1,103 37		2,574 08
Suisun refuge	2,151 77	742 68	523 54	132 00	3,549 99
Winter feeding and salting of game		475 12			475 12
Yountville game farm	16,836 55	11,075 72	4,281 75	1,735 07	33,929 09
Total Game Conservation	\$95,665 58	\$31,352 08	\$30,091 67	\$11,390 83	\$168,500 16
Licenses:					
Executive	\$3,300 00	\$60 43	\$168 68	\$1,071 20	\$4,600 31
General office	1,543 67	171 22	1,828 99	4,172 24	7,716 12
License distribution	10,987 63	17,856 78	60,973 23	355 15	90,172 79
Total Licenses	\$15,831 30	\$18,088 43	\$62,970 90	\$5,598 59	\$102,489 22

STATEMENT OF EXPENDITURES—Continued

For the Period July 1, 1937, to June 30, 1938, of the Eighty-ninth Fiscal Year

Function	Salaries and wages	Materials and supplies	Service and expense	Property and equipment	Total
Special Items:					
Cons. of research boat.....				\$37,804 00	\$37,804 00
Improvement of office, Ferry Bldg., San Francisco.....			\$25,000 00		25,000 00
Total Special Items.....			\$25,000 00	\$37,804 00	\$62,804 00
Total 89th fiscal year expenses paid from Support appropriations.....					\$137,830 82
Claim of Chief Accounting Officer, Dept. of Finance, Ch. 772-37.....					3,293 65
Expenditures for Additions and Betterments:					
Permanent Improvements:					
Purchase of game refuges and public shooting grounds and C. I. E., Ch. 157-37.....	\$3,603 09	\$8,968 02	\$2,036 29	\$1,690 85	\$16,298 25
Contributions to Employees' Retirement System.....					23,948 80
Total current biennium.....					\$1,422,371 52
89th fiscal year:					
Special Item: Expenses of California Code Commission, Ch. 645-33.....				\$0 37	\$0 37
Support:					
Eighty-eighth fiscal year.....				\$53 57	
Eighty-fifth fiscal year.....				106 50	
Total Support.....					\$160 07
Special Item: Predatory animal control, 85th fiscal year.....				—\$106 50	—\$106 50
Total prior biennium appropriations.....					\$53 94
Grand total.....					\$1,422,425 46

SEIZURES OF FISH AND GAME

April, May, June, 1938

Game:

Beaver skin	1
Bird traps	2
Brant, black sea	1
Deer	1
Deer meat, pounds	954
Doves	17
Ducks	4
Duck eggs	11
Goose, Canada	1
Meadow lark	1
Pheasants	12
Pigeon	1
Quail	5
Rabbits	36
Sandpiper	1
Sparrows	17
Squirrels	2
Squirrel hides	2
Turkey	2

Fish:

Abalone	738
Abalone, pounds	40
Barracuda, pounds	11
Bass—	
Black	153
Black, pounds	34
Large Mouth Black	18
Sand, pounds	200
Striped	351
Striped, pounds	288
Bass traps	6
Bluegills	149
Carp, pounds	40
Catfish, pounds	161½
Clams	3,522
Crabs	51
Crabs, dozen	4
Crab nets	8
Crappie	75
Fyke nets	4
Halibut	17
Lake Tahoe trout, pounds	40
Lobsters	55
Lobsters, dozens	3
Lobster pots	3
Lobster traps	13
Perch	32
Rainbow trout	35
Salmon, pounds	4,666
Steelhead trout	124
Sturgeon	2
Sunfish	473
Trout	516

GAME CASES

April, May, June, 1938

Offense	Number arrests	Fines imposed	Jail sentences (days)
Beaver; using sawtooth traps	1		
Bird nets; possession	1	\$50 00	
Brant; black sea, closed season	1	50 00	
Deer; possession of, deer meat, closed season, illegal light and rifle in deer country, killing female, possess parts of spike buck, allowing dogs to run deer, possess venison, closed season	54	3,295 00	1,260
Doves; taking, possession, closed season, no license	6	55 00	
Ducks; possession closed season, shoot closed season, take wild duck eggs	11	175 00	
Firearms; possession in game refuge	1	75 00	
Game birds; shoot at in game refuge, take, possession closed season	4	40 00	
Goose; illegal possession	2	50 00	
Hunting; no license, with spotlight, night	20	245 00	17½
Killdeer; taking	1		
Net; larger than 6 feet to take bait	1	25 00	
Nongame birds; possession	3	20 00	
Pheasants; possession closed season, no license, shoot from auto, male close season	19	530 00	72½
Quail; desert, closed season	6	144 00	43
Rabbits; no license, take cottontails during closed season, shoot from auto, take with spotlight, night hunting	30	327 50	10
Shore birds; possession avocet	2	40 00	
Squirrels; possession portions, possession grey squirrel hides	4	70 00	
Trapping; no license	2	20 00	
Totals	169	\$5,211 50	1,403

FISH CASES

April, May, June, 1938

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalones; undersized red, closed season, overlimit, no license	104	\$1,740 00	
Angling; no license	62	632 00	42½
Barracuda; take with net during closed season	1	100 00	
Bass; sell striped, take striped in salmon net, possession black bass during closed season, striped no license, possession overlimit striped, possession black bass less than 9 in. in length, striped less than 12 in.	83	1,315 00	14½
Bluegills; closed season	7	104 00	
Catfish; retaining catfish less than 9 in. in live box, possession for sale less than 7 in. dressed, seining	5	50 00	
Clams; overlimit pismo, take cockles no license, possession in clam refuge, possession implement capable of digging clams in a clam refuge, out of shell, overlimit razor clams, overlimit, undersize cockles, overlimit Washington	53	795 00	65
Cockles; taking, no license	2	20 00	
Commercial fishing, no license	31	110 00	12½
Crabs; possession undersized, remove from District 1½ to District 2	23	530 00	
Crappie; taking closed season, no license	16	130 00	
Crustaceans; fail to show on demand	1		
Diving for commercial purposes in less than 20 feet of water	1	100 00	
Drift gill net; illegal mesh, operate in Sacramento River without floats or buoys	6	70 00	
Fail to keep record of fish bought	5	1,800 00	50
Fail to show license on demand	37	275 00	
False statement in procuring an angling license	1	5 00	
Fishing within 150 feet of the lower side of dam, within 250 feet of the lower side of fishway, in fish refuge, in closed district, in inlet of lake, in closed stream, night, closed season, too close to fish ladder	31	365 00	
Fyke nets in District 12-A, closed season	1		
Gaff; possession of	1	10 00	
Game fish; possession during closed season, take without license	36	415 00	
Gill net in closed district, in District 20	3	50 00	
Illegal fishing; perch, crappie, calico bass	1	5 00	
Illegal gear	1	10 00	
Lobsters; possession unmarked during closed season, possession spiny less than 10½ in. long, closed season, take in trammel net, operate trap in closed district	7	175 00	
Mackerel; take with illegal net in District 20	14	850 00	
Perch; closed season	12	153 00	15½
Pollution	12	1,650 00	
Salmon; possession undersized Chinook	2	25 00	
Set lines; operating with 100-hook in San Joaquin River	5	25 00	185
Steelhead; gaffing, possessing unlawfully taken	6	25 00	20
Sturgeon; possession	1		
Sunfish; take closed season, no license	43	690 00	37
Transferring license to another angler, using another's license	6	38 00	
Trout; closed season, no license, set line, fishing for trout in a fish refuge, overlimit, take with set line	53	957 00	47
Totals	673	\$13,219 00	489

FRESH FISH IMPORTATIONS FROM OTHER STATES AND FOREIGN COUNTRIES

April, 1938

	Oregon and Washington	Gulf of California	Japan
For canneries:			
Tuna, Albacore.....	5,538		
Tuna, Skipjack.....			698,188
For fresh fish markets:*			
Cabrilla.....		26,555	
Corbina, Mexican.....		76,648	
Sea-bass, Totuava.....		227,996	
Total pounds.....	5,538	331,199	698,188

May, 1938

	Oregon and Washington	Gulf of California	Japan
For canneries:			
Tuna, Albacore.....	500		
Tuna, Oriental.....			4,328
Tuna, Skipjack.....			1,102,028
For fresh fish markets:*			
Cabrilla.....		26,141	
Corbina, Mexican.....		1,897	
Sea-bass, Totuava.....		293,407	
Crustacean:			
Shrimp.....		3,282	
Total pounds.....	500	324,727	1,106,356

June, 1938

	Oregon and Washington	Gulf of California	Japan
For canneries:			
Tuna, Albacore.....			366,662
Tuna, Skipjack.....			1,227,115
Tuna, Yellowfin.....			49,924
For fresh fish markets:*			
Cabrilla.....		10,847	
Sea-bass, Totuava.....		115,270	
Total pounds.....		126,117	1,643,701

* This record includes only that fish which is voluntarily reported to the Division of Fish and Game and does not represent all importations.

CALIFORNIA FISH AND GAME

FRESH FISH LANDINGS OF CALIFORNIA BOATS FOR APRIL, 1938

Compiled by the Division of Fish and Game, Bureau of Marine Fisheries

Species	California waters						Waters South Inter-national Boundary		Total landings of California boats
	*Regions 10 and 20, Del Norte and Eureka	Region 30, Sacramento	Region 40, San Francisco	Region 50, Monterey	Region 60, Santa Barbara	Region 70, Los Angeles	Region 80, San Diego	Total pounds	
Anchovy			16,200	23,440		2,339		41,979	41,979
Barracuda						88,188	5,183	93,371	109,832
Cabezone			400	317	43			760	760
Carp		23,769		46				23,815	23,815
Catfish		42,593		80		14		42,657	42,657
Cultus, Pacific	23,911		21,506	6,164	196	121		50,898	50,898
Eel						32		32	32
Flounder, Starry	4,667		50,255	1,971		788		56,883	56,883
Flying Fish								788	788
Grouper									
Hake	460		150			133		763	11,029
Halibut, California			2,430	619	24,594	40,099	31,005	98,747	98,802
Halibut, Northern	42,680							42,680	42,680
Hardhead		2,555						2,555	2,555
Herring, Pacific								370	370
Kingfish				370				75,086	75,086
Mackerel, Horse			14,731	14,731	32	60,323	183	8,915	8,915
Mackerel, Pacific			8,732	1,143		2,013	527	3,683	3,683
Mullet						84	270	354	354
Perc	7,503		21,360	8,321	2,628	16,590		56,402	56,402
Pike		220						220	220
Pompano, California						29		29	29
Rock Bass					2,690	6,780	8,737	18,207	21,107
Salmon	63,455		67,419	245,922	32,106	45,760	7,709	462,371	503,476
Sablefish	5,529		6	3,035		31,680		40,350	40,350
Sardine	139,955	12,160		68,907				221,022	221,022
Sand Dab	23,601		8,630	13,420		654		46,605	46,605
Sardine				201,118		297,870	112,035	541,023	541,023
Southern					81	5,043	22,686	27,780	27,780
Sea-bass, Black					509	2,148	238	2,915	17,729
Sea-bass, Short-fin								34	34
Sea-bass, White					2,324	4,177	404	6,905	11,198
Shad		620,685		5				620,690	620,690

Shark.....	2,035		61,007	7,264	11,661	12,686	3,325	97,888	205	98,193
Sheepshead.....					30	10,729	98	10,857	298	11,155
Slate.....	7,035		26,960	23,658	3,209	1,120	68	62,035		62,035
Smelt.....			37,428	221	12,712	22,066		72,427		72,427
Sole.....	450,263		141,804	170,779	35,812		8	799,170		799,170
Split-tail.....		2,431						2,431		2,431
Sucker.....		95						95		95
Tuna, Bluefin.....						38	309	347	7,083	7,430
Tuna, Bonito.....						454	160	614	1,634	2,248
Tuna, Skipjack.....									2,043,626	2,284,114
Tuna, Yellowfin.....									3,276,923	4,047,726
Turbot.....	280		11,401	2,364				240,488		14,025
Whitebait.....	13,306		1,268	80				767,803		19,025
Whitefish.....					64	534		19,654		19,654
Yellowtail.....						4,111	24,401	598	1,008	1,836
Miscellaneous Fish.....	7,365		3,370	2,275	365	800		28,512	89,796	118,502
								14,175		14,175
Crustacean:										
Crab.....	36,466		383,696	2,498				422,660		422,660
Prawn.....				204				204		204
Shrimp.....			72,009					72,009		72,009
Mollusk:										
Abalone.....				146,875	102,975	1,702		251,552		251,552
Clam, Cockle.....			37			1,801		1,838		1,838
Clam, Gaper.....			424	100				524		524
Clam, Pismo.....				983	12,822			13,505		13,505
Clam, Razor.....	10							10		10
Clam, Soft-shell.....			7,295					7,298		7,298
Clam, Washington.....	3		285					2,738		2,738
Octopus.....	2,451		603	2,921				4,705		4,705
Oyster, Eastern.....	1,181		21,702					21,702		21,702
Oyster, Japanese.....			115,426					115,426		115,426
Oyster, Native.....			4,640					4,640		4,640
Squid.....				5,105				5,105		5,105
Total pounds.....	836,076	704,508	1,078,001	963,633	244,553	591,623	217,187	4,635,581	1,014,297	11,188,543
										5,508,665

*The eight geographical regions of the State are as follows:

Regions 10 and 20. Del Norte and Eureka; Del Norte, Humboldt and Mendocino counties.
 Region 30. Sacramento: The Sacramento and San Joaquin River systems with the delta areas, including Suisun Bay and Lake County.
 Region 40. San Francisco: Sonoma, Marin, San Francisco and San Mateo counties, including San Francisco and San Pablo bays.
 Region 50. Monterey: Santa Cruz and Monterey counties.
 Region 60. Santa Barbara: San Luis Obispo, Santa Barbara and Ventura counties.
 Region 70. Los Angeles: Los Angeles and Orange counties.
 Region 80. San Diego: San Diego and Imperial counties.

These tables are subject to slight revision due to related supplemental items.

FRESH FISH LANDINGS OF CALIFORNIA BOATS FOR MAY, 1938
 Compiled by the Division of Fish and Game, Bureau of Marine Fisheries

Species	California waters						Oregon waters	Waters South International Boundary		Total landings of California boats	
	*Regions 10 and 20, Del Norte and Eureka	Region 30, Sacramento	Region 40, San Francisco	Region 50, Monterey	Region 60, Santa Barbara	Region 70, Los Angeles		Region 80, San Diego			
Anchovy.....			129,400	2,850		2,812		135,062			135,062
Barracuda.....					813	149,438	56,970	207,221		13,400	220,621
Cabezone.....			600	150				750			750
Cabrilla.....										280	280
Carp.....		799						799			799
Crabfish.....		3,882						3,882			3,882
Clupea.....	6,801				190			27,511	150		27,661
Flounder, Starry.....	1,820					8		11,959			11,959
Flying Fish.....			9,850	289				32,846			32,846
Grouper.....						32,846				1,549	1,549
Hake.....	115		6,665	1,950		170		8,900			8,900
Halibut, California.....	320		207	512	21,096	10,025	8,603	46,783			46,783
Halibut, Northern.....	41,348							41,348		6,051	47,399
Kingfish.....			2,824	10,613	55	44,922		58,414	175		58,428
Mackerel, Horse.....				8,572		60	7,765	16,397		14	16,397
Mackerel, Pacific.....				50,478	159	4,259	12,375	67,271			67,271
Mullet.....							1,147	1,147			1,147
Perch.....						1,403		1,403			1,403
Pompano, California.....						42		42			42
Rock Bass.....					1,046	15,442	6,169	22,657		2,241	24,898
Rockfish.....	18,144		30,157	186,523	13,818	22,192	13,866	284,700		3,084	287,784
Sablefish.....	5,840		82		4	7,924		19,701			19,701
Salmon.....	50,905	33,689	4,374	89,764	38			178,770			178,770
Sand Dab.....	13,950		50,939	1,517		259		66,665			66,665
Sardine.....			88,500	328,835	445	20,523	68,487	506,790	175		506,790
Sculpin.....					21	12,568	7,189	19,778			19,778
Sea-bass, Black.....					252	5,967	582	6,501		89	6,590
Sea-bass, Short-fin.....							806			8,544	8,550
Sea-bass, White.....					953	10,703	2,766	14,422		8,555	23,900
Shad.....											806
Shark.....	88	704,858	2,670	2,182	51,569	36,638	6,421	704,858		6,253	704,858
Sheepshead.....					262	6,746	167	99,568		761	100,329
Skate.....	7,620		20,770	9,537	3,616	1,092	70	42,705			42,790

Sheepshead	9,680		287	4,105	10	4,402	4,402
Skate	542	8,370	3,056	1,464		31,379	31,379
Smelt	459,657	16,896	1,325	16,297	532	46,706	46,706
Sole		207,697	12,599	1,379	15	750,171	750,171
Swordfish, Broadbill			2,009	13,968	14,863	30,540	31,188
Tongcod	130					130	130
Tuna, Bluefin				2,307,250	542,977	2,850,227	2,925,254
Tuna, Bonito				13,886	362,963	376,849	377,411
Tuna, Skipjack						955,517	955,517
Tuna, Yellowfin						1,859,193	1,859,193
Turbot	350						
Whitebait	25,343	6,144					
Whitfish		210	21	629		27,085	27,085
Yellowtail				6,008	56,627	62,635	63,004
Miscellaneous Fish	12,855	1,757	2,306	4,602		24,001	24,001
Crustacean:							
Crab	43,446	261,766		775		312,110	312,110
Crab, Rock						775	775
Shrimp		282,313				282,313	282,313
Mollusk:							
Abalone							
Clam, Cockle			84,100	450		209,325	209,325
Clam, Gaper		23		2,513		2,536	2,536
Clam, Pismo		360				540	540
Clam, Razor	280		20,133			20,133	20,133
Clam, Soft-shell						280	280
Clam, Washington						7,789	7,789
Octopus						235	235
Oyster, Eastern	4	1,255				6,089	6,089
Oyster, Japanese		16,750				16,750	16,750
Oyster, Native		4,113				61,717	61,717
Squid						4,113	4,113
Total pounds	1,309,580	1,195,321	596,437	3,123,811	1,927,145	9,668,799	22,855,735

*See footnote to table for April.

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Karl Lund, Assistant Warden, Cruiser "Tuna"	Avalon
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L. L. Werder, Assistant Warden	San Francisco

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Motor Vessel "Albacore,"	Monterey
Cruiser "Yellowtail,"	Newport Harbor
Cruiser "Broadbill,"	Santa Monica
Cruiser "Quinnat III,"	San Francisco
Cruiser "Bonito,"	Santa Barbara
Cruiser "Marlin,"	San Diego
Cruiser "Tuna,"	Avalon
Launch "Rainbow,"	Sacramento
Launch "Shrapnel,"	Lakeport
Launch "Silver-side,"	Eureka
Launch "Sturgeon,"	Martinez